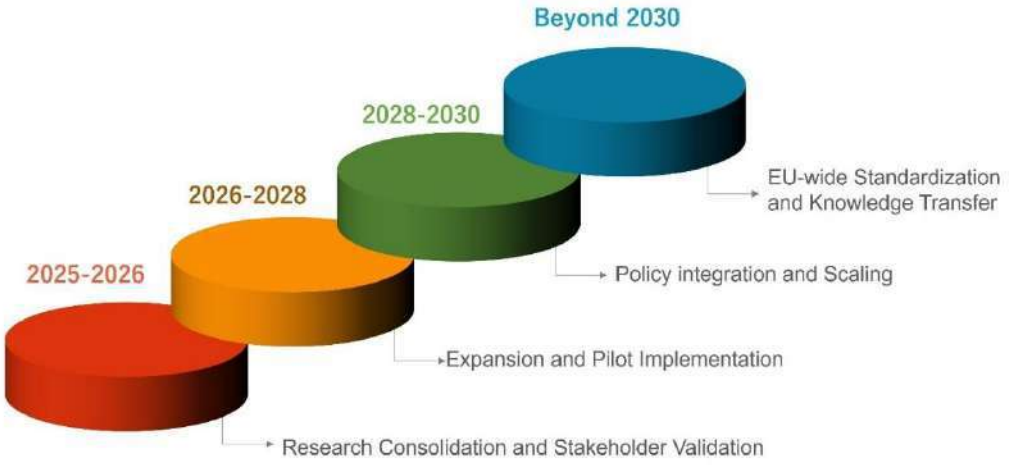

Figure 68: Strategic priorities (above) and Roadmap toward Institutional Adoption of Scenario-Based Wildfire Risk Planning (below).

Year 1 (2025-2026)
Finalize research and development of the IA 2.4 tool. Validate methodology with key national stakeholders. Publish findings, technical documentation, and case studies. Organize dissemination events and workshops to build awareness.
Years 2-3 (2026-2028)
Expand pilot use of IA 2.4 to additional Greek regions and select EU countries. Develop and launch a user-friendly web platform for broader accessibility. Provide training sessions for national and regional planners. Adapt methodology for different national contexts and landscapes.
Years 4-5 (2028-2030)
Support integration of IA 2.4 into national wildfire and land management policy frameworks. Establish treatment plans based on IA 2.4 outcomes at both regional and national levels. Promote policy adjustments for institutional adoption and budgeting alignment.
Beyond 2030
Advocate for IA 2.4 adoption as an EU best practice for wildfire resilience planning. Collaborate with EU institutions to support harmonization and standardization. Enable knowledge transfer, replication, and cross-border application of the tool.

A multi-actor collaboration strategy is necessary for the IA 2.4 roadmap's successful implementation and long-term effects. Together with the Community of Wildfire Innovation (CWI), the University of the Aegean (UAEGEAN) will oversee activity coordination, offer technical assistance, and conduct focused training. In order to validate the tool and incorporate it into their operational planning and response processes, the Fire Brigade and Forest Service are essential. It is anticipated that the Ministry of Environment and Climate will support the approach and help scale it through national initiatives and financial tools. In order to enable localized planning and experimentation, regional authorities will take the lead in implementing IA 2.4 in specific territories. To

guide investment and risk-reduction plans, the private sector—including energy suppliers and hotel owners in high-risk areas—is urged to use the tool. The transmission, co-development, and ultimate standardization of the technique at a wider European level will be supported by collaborations with EU and international stakeholders, which are based on the FIRE-RES stakeholder database.

The IA 2.4 Scenario Planning technique, which is based on the ForSys optimization tool, will be used to implement the plan. This programme integrates stochastic fire simulations and spatial data to identify high-risk zones, allowing the development of risk-prioritized fuel treatment plans. The method will be made accessible through a WebGIS interface and supported by interactive training sessions to ensure broad stakeholder adoption. Key performance indicators (KPIs) will be utilized to guide progress. These include the percentage of risk-based treatment sites selected, measurable reductions in fire exposure, and more transparency in planning and funding decisions.

The methodology is anticipated to contribute to a 15% reduction in the total burned area and a 10% reduction in the number of buildings affected by wildfires, contingent on the level of public investment and acceptability. The tool will help with both risk reduction and long-term adaptation by integrating fire resilience into territorial and spatial planning. It will also increase multi-agency cooperation, encourage stakeholder participation, and increase public trust in wildfire prevention strategies.

10.5. CWI feedback

After the FIRE-RES CWI meetings, the organizers distributed a feedback form with 20 Likert scaled questions ranked from 1 (fully agree) to 5 (fully disagree), and three open questions. The Likert scaled questions aimed to receive feedback from the organization of the event, while the open questions aimed to capture the impressions and expectations of CWI members regarding FIRE-RES project, as well as suggestions to improve future CWI meetings. From the responses collected, we highlight that the CWI participants were very satisfied (100%) with the organization of the event, that the objectives and messages were clear, the expectations were fulfilled, and that the discussions were helpful for their future work development. Overall, the CWI participants indicated interest in participating in the conversation, attending upcoming meetings, and taking part in Innovation Actions initiatives.

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11. Norway-Sweden (NOR-SW)

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11.1. Wildfire context

From an international perspective, and compared to other LLs, the problem of wildfires is relatively small in NOR-SW. While extreme fire weather is uncommon, severe conditions do occur with regularity, such as the summer of 2018 (Granström, 2020), the Norwegian January fires of 2014 (Log et al., 2017), and the extreme Västmanland fire (2014) (Köhler et al., 2018).

From the recent report "Forest fires in the Nordic region, SNS 2021":

> Forest fires are a common hazard in Nordic forests and play a crucial role in the development and shaping of natural vegetation. Typical fires in the Nordics are characterised by their narrow reach. Between 2000 and 2017, the range of average forest fires in Sweden and Finland was under one hectare, except for 2006, 2008, and 2014, where they exceeded the one-hectare threshold. Norway is the country in the region where fires are generally the most extensive. Under the same period, average fires were under 8 hectares except for 2006, 2008, 2009, and 2010, where they exceeded the 8-hectare threshold.
> A general historical trend of decreased forest fire activity has been observed throughout Northern Europe since the introduction of efficient fire suppression policies during the 19th century. Fire regimes can, however, change depending on topography, climate, and available fuel. In the past few years, the decreasing trend has halted in favour of an increase of forest and vegetation fires in the Nordics. Notably, the intensity of the fire regimes in the Nordics is increasing, evolving from rare fires of small intensity directly into potential megafires.

And

> Northern Europe is the most forested region with percent of land covered by trees. 45 percent of forests in Europe are mainly coniferous, 36 percent are predominantly broadleaved, while the remaining share is mixed. The Nordic region is dominated by boreal forests with about 75 percent of the growing stock composed of coniferous species, which is different from the forest structure in southern Europe.

11.1.1. Fire regime, socio-ecological context, and impacts

Fire seasons have primarily occurred during Spring and summer. Higher numbers of fires occur around densely populated areas, and most firefighting efforts are carried out from April to August. However, changes in the local climate conditions such as prolonged periods of drought in the autumn, after snow melt – and in areas with snow-free winters – pose a high risk of grass and heather fires and can result in fire events even during the winter, such as the fire in Lærdal in January 2014 (Log et al., 2017)

Nine out of ten forest fires are caused by human activity (Skogbrand page), and Lightning is the most common natural cause of forest fires. *In Norway,* despite the abrupt topography, most fires do not spread quickly enough to exceed extinguishing capacity. Some exceptions are the Lærdalsøyri fire, in which the fire had a very fast fire development, and the strong winds spread the fire long distances (Log et al. 2019) .

The Nordic forest is dominated by three native species: Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), and deciduous trees (mainly *Betula spp.*). Pine and spruce forests are more prone to intense crown fires. Pine forests usually have light-open crowns and drought-weak ground vegetation of heather, mosses, and lichens, which are most vulnerable to forest fires (Søgaard et al. 2020). The fire risk in spruce forests is less due to more moisture. In addition, the forest floor is often species-poor, and the proportion of moist species of herbs and grasses is greater than the proportion of drought-prone heather species, which results in less flammable fuel on the forest floor. Deciduous forests are usually moister and tend to burn more slowly or to resist fire.

In Sweden, Lodgepole pine (*Pinus contorta*) has been introduced and covers part of the inland north. This pine has more surface fuel bed mass, a more porous structure due to its longer needles, and an increased fuel ladder towards the crown, which makes it more fire-prone compared to the native species. (Granström, 1998)

Even though traditional WUI definitions may not be entirely suitable for this LL due to the sparse building density, if we consider it as areas where “vegetation fires damage structures,” both interface WUIs and intermix WUIs are common, and many of the larger cities and towns are surrounded by nature. (Gribble et al., 2025)

The WUI is scattered throughout the region, with the highest concentration found in the southern part of both countries, where a higher percentage of the population resides. Both countries have a tradition of constructing houses and cabins from timber, which adds an extra layer of vulnerability. There are no wildfire risk awareness and prevention programmes addressed to the people living in the WUI (Medina et al., 2025). Some insurance companies for forests offer help with emergency preparedness and prevention of forest damage and wildfires. As well as guidelines for forest management during fire season, but no regulation mandates following them.

11.1.2. Wildfire governance

In Norway, there are no specific regulations related to wildfire management, but there are three documents with rules related to fires:

- **The Fire and Explosion Protection Act (LOV-2003-06-14-20).** This national law aims to protect life, health, the environment, and property from fire, explosions, and accidents involving hazardous substances. It outlines the responsibilities of individuals, municipalities, and the fire and rescue services.
- **The Regulation on fire prevention (FOR-2015-12-17-1710),** which provides detailed rules to reduce the likelihood and consequences of fires. It contains the general duty of care not to leave fires unattended until they are completely extinguished (§ 3) as the rule for a seasonal band. From 15 April to 15 September, it is prohibited to light fires or use flammable materials in or near forests and other uncultivated land. (**§ 5**)
- **The Regulations on the organization, staffing and equipment of the fire and rescue services and the emergency reporting centres (FOR-2021-09-15-2755)** which among other risk it include wildfires events and how the Municipalities must conduct a preparedness analysis (§ 9) and have plans in place for handling those incidents (**§ 10**) or that the fire service must implement temporary increased preparedness, in periods of hight risk which may include additional staffing or equipment (**§ 18**)

Sweden has a more integrated legal framework for wildfire prevention and response with various laws and regulations that govern the roles and responsibilities

- **The Forestry Act (Skogsvårdslagen (1979:429)** declares forests a national asset and mandates sustainable forest management that preserves biodiversity and minimizes wildfire risks through responsible practices.
- **The Civil Protection Act. (Lagen om skydd mot olyckor (2003:778)** establishes responsibilities for individuals, municipalities, and the state to prevent and manage accidents, including wildfires. It states that municipal fire brigades are responsible for suppression, while Landowners or property holders are responsible for preventive measures and, after the fire is extinguished, for monitoring and guarding scorched areas to prevent re-ignition or further damage
- **The Swedish Environmental Code (Miljöbalk (1998:808)** promotes sustainable development and environmental protection. While not wildfire-specific, it requires land use and forestry to be conducted in ways that reduce environmental risks, including fire hazards. It also regulates public access rights (allemansrätten), requiring individuals to act with care in nature

Outdoor fire-making is further regulated by local ordinances and civil protection rules. Forest owners and contractors also have obligations under private insurance policies and industry standards to manage fire risks.

Wildfire preparedness is reduced. Active forest management actions aimed at creating resilient landscapes are currently limited and are generally not contemplated in forest management plans (SNS 2024). Prescribed burnings are used on a very limited scale; the general public's attitude is to avoid all fires.

Fighting the fires is the municipality's responsibility through local fire and rescue services, with assistance from the Civil Defence and the Home Guard/volunteers. The figure of a fire analyst doesn't exist, at least in Norway.

The general policy is to prevent all fires and minimize damage to forests, people, and infrastructure. Current efforts focus on early detection, rapid response, and suppression. This is facilitated by the active forestry management in both countries and the extensive network of forest roads.

Post-fire actions are not regulated, and the forest owner is responsible for restoration efforts. This includes making decisions and ensuring that the fire does not reignite. There are limited strategic or tactical plans for what must be done after an incident; however, forest owners who have certified their forest must comply with the Norwegian/Swedish PEFC forest standard's requirements for managing fire-affected forest areas (PEFC Norway, 2015). Moreover, the information collected after a fire is insufficient. In the case of Norway, basic information such as the ignition point, cause of fire, meteorological data, or fire perimeters are generally not recorded.

11.2. Vision for wildfire-resilient landscapes in 2030

Projections of future climate conditions indicate higher temperatures and more frequent extreme drought periods for the Nordic region. In anticipation of the increased risk and higher occurrence of wildfire events, the 2030 vision focuses on being prepared by capacity building, knowledge sharing, and training to minimize the impact on the environment, economy, and society.

11.2.1. A 2030 wildfire-resilient landscape in Norway - Sweden

The shared understanding of a wildfire-resilient landscape for the CWI in this Living Lab involves long-term resilient ecosystems through Integrated Fire Management, where we benefit from the ecological aspects of wildfires while minimizing harm to communities, infrastructure, and natural resources. The vision goes towards a more comprehensive and holistic approach, recognising that it requires a multifaceted strategy linking the entire fire cycle and its components: 1) Prevention & Preparedness; 2) Detection & Response; 3) Adaptation & Restoration.

11.2.2. Resilience in fire preparedness and prevention

The vision for 2030 is to enhance preparation and awareness of wildfire risk and to align the vision across stakeholders. In Norway, a fire ban prohibiting any type of open fire is in effect from 15 April to 15 September. Additionally, Municipalities can impose fire bans at any time of year and anywhere outdoors if the fire risk is high. In Sweden, bans are not fixed to dates but are imposed when needed by county administrative boards or municipalities.

While these measures help reduce fire ignitions and prevent many accidents, it is crucial to increase public awareness about fire risks and the collective responsibility of preventing fire ignitions. Fire suppression should not be viewed as the sole responsibility of fire departments. There must be a broad understanding of wildfire risks, as well as awareness of the dangers associated with forest and silvicultural activities during dry and hot weather. It is also important to inform and promote preventive measures to protect assets and infrastructure. Furthermore, fire mitigation should be integrated into forest management, landscape planning, and community preparedness analysis for wildfires.

11.2.3. Resilience in wildfire emergency management

The vision for 2030 emphasizes enhanced cooperation among authorities, local communities, forest owners, and firefighting services. The goal is to improve the safety, efficiency, and training of local fire and rescue services, while also providing better tools for estimating fire behaviour and supporting informed decision-making during wildfire events. This includes improving and increasing the number and quality of data recorded in databases, such as ignition start points, local weather conditions, accurate fire perimeters, and fuel types.

11.2.4. Resilience in post-fire management and adaptation

Resilience and post-fire management have not been a challenge in the NOR-SW LL, as most fires have been small. However, there are no regulations or strategic and tactical plans outlining the necessary actions to take after an incident. Therefore, while it may be ambitious to achieve by 2030, the goal should be to establish regulations for post-incident actions, clarify responsibilities, and establish plans and frameworks for post-fire management after each type of wildfire.

11.2.5. Other resilience aspects

In a future with more extreme weather in the Nordic countries, it is possible that EWE may occur here, and therefore, knowledge about this type of fire needs to be increased, and preventive measures implemented.

11.3. Gaps to reach that vision

11.3.1. Preparedness phase

The reduced number of fires and the lack of EWE lead to a low perception of risk from society, as well as from the administration, which contributes to a lack of legislation, funding, preparedness, and readiness.

There is a need for a national wildfire dialogue to align visions across stakeholders, facilitate knowledge sharing, promote continuous training for ground forest fire fighters, and foster international cooperation that ensures good preparedness for the times ahead.

11.3.2. Prevention phase

The landscape is changing. For example, the introduction of Pinus contorta in Sweden is now entering its second rotation and is expected to increase, leading to a greater accumulation of flammable litter. However, as mentioned earlier, wildfire risk is rarely addressed in forest management plans, and there are no mitigation methods in place, nor are there management activities to reduce wildfire risk, such as fuel reduction or the creation of fuel breaks.

It is not uncommon in the forest management plans to include aggressive pre-commercial thinning that completely removes deciduous species, contributing to the creation of more flammable fuel beds for the duration of the stands' lifetimes (Sjöström et al., 2025). Evaluating these practices in the context of wildfires and replacing them with more effective management strategies that reduce fire risk is necessary. Long-term forest management efforts are important to limit all types of fires, but crucial in EWE that cannot be extinguished by human intervention (SNS, 2019).

11.3.3. Detection phase

Detection methods in Norway and Sweden include the use of airplanes, forest fire towers, and reports from private individuals via phone. Additionally, Sweden has implemented an automatic satellite-based detection system to enhance its fire monitoring capabilities. During periods of high fire risk and when fire warnings are issued, extra measures are mobilized in both countries to enhance firefighting efforts.

One challenge will be that the number of fires may increase, leading to a late detection of fires. More fires will increase the risk that some fires escalate into EWE, for example, in remote areas.

11.3.4. Response phase

The primary challenge to a proper response is the lack of experience, particularly in cases involving EWE or simultaneous fires. There are also coordination difficulties due to jurisdictional differences. Therefore, there is a need for:

- Improved command and control and a common framework for characterizing wildfires, in order to quickly establish a shared understanding of the situation and make informed decisions regarding who to involve at the right point in time, how

to allocate available resources properly, and how to coordinate the large-scale response effort efficiently, including volunteers.
- Better supporting decision-making tools are necessary, such as maps, simulation tools, and input variables suitable for Nordic conditions.
- Strengthen data-sharing
- Strengthen cross-border collaboration between Norway and Sweden.

11.3.5. Restoration and adaptation phases

Currently, restoration after a fire depends on the forest owner, including mop-up and controlling the extinguished fires for re-ignitions. This is a significant responsibility; the poor mop-up was one of the major key components in the devastating summer of 2018 in Sweden (Granström, 2020), and forest owners often lack the proper training or knowledge to perform these tasks.

There is a need for training and guidelines for restoration after wildfires. Plans for restoration could also consider restoration after EWEs.

11.3.6. Other challenges

The responsibility for preventing, planning, and extinguishing fires is divided between individuals, owners, municipalities, and the state. The variety of stakeholders, the extensive forest areas in these countries, and the Right to Public Access, which includes private land, contribute to the challenges of wildfire management. Many different actors need to work together to prevent and effectively extinguish wildfires if they do occur.

Furthermore, fighting wildfires is expensive, and being prepared for new paradigms requires training, resources, and new approaches. Wildfires are a common but not alarming hazard; there is a general low perception of risk associated with them, and therefore, they are not a priority. Insufficient budget allocations for wildfire management, which are necessary to maintain and enhance current resources and services, could become a significant limiting factor.

11.4. Steps and milestones: the roadmap

11.4.1. Progress achieved during the project (at CWI level)

To date, a total of three meetings have been conducted. The participant organizations for each are listed in Table 14. The NOR-SW LL approach has been to build a community of people interested in fires to share knowledge, ideas, and have a point for debate and communication. We utilized established networks as the primary channel for communication between FIRE-RES and stakeholders and we did not force commitment through the project. The wildfire community in the NOR-SW LL is relatively small, and it is

meaningful to use existing networks. In our opinion, this approach has been positive and resulted in higher attendance at the meetings.

1. **20th October 2022 in Trysil**. Was a two-day meeting co-organized with the existing network "Nordisk nettverk for skog- og vegetasjonsbranner". The objective of the meeting was to launch the Community of Wildfire Innovation in NOR-SW LL, discuss the current state of wildfires across the Nordic countries, and foster dialogue around the challenges and future perspectives of forest fire management. The meeting concluded with a visit to the 2018 wildfire site in Ljørdalen to observe and reflect on the post-fire conditions of the LL and lessons learned. A total of 13 persons from 11 organizations attended this meeting, and the outcome was the drafting of the vision and challenges of the Nor-SW LL.
2. ***14th September 2023 in Oslo***. The objective of the meeting was to present the FIRE-RES and TREEADS EU projects, discuss the results achieved so far in the LL, and continue working collaboratively on the development of the LL roadmap. Additionally, the meeting aimed to explore wildfire-related topics among the participants. A total of 34 participants, representing 22 different organizations and stakeholders in Norway and Sweden, attended this meeting. The outcome of the meeting was an agreement on the need for better wildfire-resilient landscapes in Norway and Sweden, the initiation of some WUI guidelines, and a shared opinion that prevention should be the focus in the LL.
3. ***19th September 2024 in Oslo***. The objective of the meeting was to present the work done in the EU projects FIRE-RES, TREEADS, and FirEUrisk, use them as a base to discuss wildfire-related topics, and keep working on the LL roadmap. A total of 27 people attended this meeting. Some of the topics discussed included challenges, future needs, and solutions for wildfires in Scandinavia, as well as strategies to mitigate the negative impact of societal trends and land-use legacies on future wildfire situations. Participants provided positive feedback, highlighting the workshop's relevance and its role in shaping future wildfire management strategies in the NOW-SW LL.

Figure 69: Group pictures from the 1st and 2nd CWI meetings.

Other activities during the project include two stakeholder meetings, one with participants in "Skogbrannutvalget" and the other for command and support officers in the "Lederstøtte" team. In the latter, there were 15 participants from 6 different organizations, with 20% being women.

In addition, two training **workshops** are organized in the Norway-Sweden LL. They were organized as part of the technical training workshops in WP 4 (Task 4.3). Training workshops for first responders are an important factor in transferring knowledge from other countries to the Norway-Sweden LL. The workshops are organized as a fire behaviour induction course at ground level & incident management level, with first responders participating. The training workshops were arranged first in Rosersberg in Sweden, 3rd to 7th of February in 2025, with a second workshop planned for October 2025.

Figure 70: Picture of one of the training workshops organized in the Norway-Sweden LL.

11.4.2. The IA demonstration results at LL level

IA1.1 Forest Fire Potential Polygons methodology to improve decision making

Norway was included in knowledge exchanges regarding the Fire Potential Polygons methodology. Although a full implementation was not initially planned, CFRS shared best practices and the conceptual framework during project-related exchanges. Further details about these engagements are expected to be finalized.

IA1.3 Early-warning indicators of EWEs

Accurate and timely warnings are essential to prevent and mitigate the impacts of EWE. In IA1.3 we used advanced probabilistic modelling to forecast the daily occurrence of EWEs at an 8 km resolution across Europe up to 9 days in advance. Our model significantly improved the current estimation of EWE probability while providing key insights into the environmental and climatic drivers of EWEs. Compared to the Fire Weather Index (FWI), our model increased precision by a factor 5 for EWE predictions at the NUTS3 level and by a factor of 10 at 8km resolution. To assess further assess it operational relevance, we

evaluated the model's forecasting skill in a test area. Our results demonstrate that EWE forecasts up to nine days in advance outperformed FWI- based nowcasts, emphasizing the model's potential for operational use and its superiority in anticipating EWEs compared to current fire danger rating systems

IA2.1 Data acquisition for landscape design

A dynamic, high-resolution map of forest and fuel conditions has been developed and implemented in the Norway-Sweden Living Lab as part of subtask 2.1.1. This work included the creation of a 16-meter resolution fuel map based on the fuel models described by Scott & Burgan (2005), as well as several change detection models using Sentinel-2 imagery.

The map was developed and tested throughout 2023 and 2024, and for 2025, it has been available to selected stakeholders via a Web Map Service (WMS). The online portal displays multiple layers, including predictions of new clear-cut harvests, bark beetle attacks, burned areas, and newly constructed forest roads. These layers also serve as inputs for updating the fuel map, supporting near-real-time monitoring. The results and lessons learned from subtask 2.1.1 will be further documented in D2.10, to be finalized in October 2025 (M47).

IA4.7 Interoperability evaluation tool

Historically, IA 4.7 has been used in NSLL, retrospectively to a European Union Civil Protection Mechanism (EUCPM) activation, which was initiated in response to wildfires in Sweden. After this operation, the collaboration between Swedish and French responders was monitored, and the matrixial tool was used to produce independent evaluations by the head of the French detachment Colonel P. SCHALLER and the Swedish official (MSB) E. EDGART. Each evaluator provided an evaluation level of 1-5 for each interoperability component (Eval 1 and Eval 2). These evaluation levels were then multiplied by their associated component weights to produce component scores (Score 1 and Score 2). Overall scores were calculated by adding up the component scores. The results demonstrates that the overall scores were quite similar despite the different nationalities of the evaluators. The tool also highlights very clearly the interoperability components that need to be improved (SOPs, training and technologies), as well as noticeable differences in perceptions of interoperability within the first four components. These differences, as well as the areas with lower scores, are valuable guides to further discussion and remedial action.

IA5.4 Models for fire combustion and pyrocumulonimbus

In IA5.4, the modelling capabilities of FDS (Fire Dynamics Simulator) were applied to the combustion of pine needles, for which the Norway-Sweden LL provided measurement data on the heat development rate of the burning material. The test data were used to build an FDS material model, which represents the combustion of fallen needles. In the method used, a fire experiment is first modelled, in which the parameters are adjusted so that the simulation produces the results obtained in the fire experiment. The optimized parameters are then used to build a model that simulates the real

environment. Two different FDS modelling methods were used for modelling, the pyrolysis surface model and the so-called boundary fuel model. The latter is used to describe the forest fire load when the computational grid resolution is such that the fire load cannot be described accurately (each tree, branch, blade of grass, etc.), but the vegetation is described as an averaged porous material. The vegetation initially contains dry material and moisture. Moisture evaporates during heating of the material, and the dry material undergoes a pyrolysis reaction, in which carbon and fuel gases are formed. The carbon is oxidized, and ash and unburned gases are formed. To test the developed material models, a larger-scale FDS simulation was performed, to demonstrate a fire spreading forward in a layer of pine needles. As a sensitivity analysis, layers of different thicknesses were simulated. It was found that thinner layers are unable to sustain a spreading fire in this scenario. The results of the simulations illustrate the existing capabilities to model forest fires when detailed information on the fuel amount is available.

IA5.10 Pan-European system to define management priorities

The innovation action "Pan-European System to Define Management Priorities for Mitigating Fire Impact" aimed to design a prototype system for identifying strategic fuel management priorities based on multiple criteria.

To develop this system, we began by defining a set of relevant criteria and assessing the need to model and map these variables. Among the most critical variables were fuel accumulation and potential fire behaviour, which, at the start of the project, were not adequately covered by existing information. During the initial years, the University of Padova mapped all fuel-related variables necessary to estimate fuel accumulation and simulate fire behaviour. This effort resulted in four scientific articles and the development of a server where the information is publicly available for download (https://www.cirgeo.unipd.it/fire-res/app/). Technosylva used this data to simulate high-intensity fire behaviour across the EU. Simultaneously, ISCI developed a multi-criteria decision support system calibrated to the generated data. This system can assign priority scores once the data is harmonized, and criteria are weighted accordingly. Currently, a strategic prioritization exercise is underway for the Iberian Peninsula, demonstrating the supranational capacity of this analysis and illustrating how large-scale, policy-oriented frameworks are most suited for this system. After the Iberian exercise is completed, the multi-criteria system, programmed as a QGIS plugin, will be publicly available.

Looking ahead, we plan to develop a dedicated server where users can easily download relevant data for such analyses. This platform will also store new data, especially concerning values and risk assessments, alongside existing datasets.

11.4.3. Next steps until 2030

To achieve the described vision and tackle some of the challenges, we proposed a Roadmap that focuses primarily on building a strong community of stakeholders. Such a

community will raise awareness of wildfire risk and ensure that the work towards resilient landscapes continues after the project concludes. Additionally, this roadmap aims to share knowledge and learn from the experiences of other countries, thereby improving preparedness, prevention, and response efforts for future wildfire scenarios.

1. Start a national and international wildfire dialogue, build a community of wildfire actors, and foster collaboration among them (CWI meetings).
2. Raise awareness of the current and future wildfire risk, explore our strengths, and the limitations of the current system.
3. Adapt knowledge and lessons learned from southern Europe to the current and future conditions in the Nordic countries.
4. Capacity building and training for response, including the creation and promotion of new technologies and data sources to be used in the different risk management phases.
5. Evaluation and validation of proposed methodologies, define future work, and specific milestones.

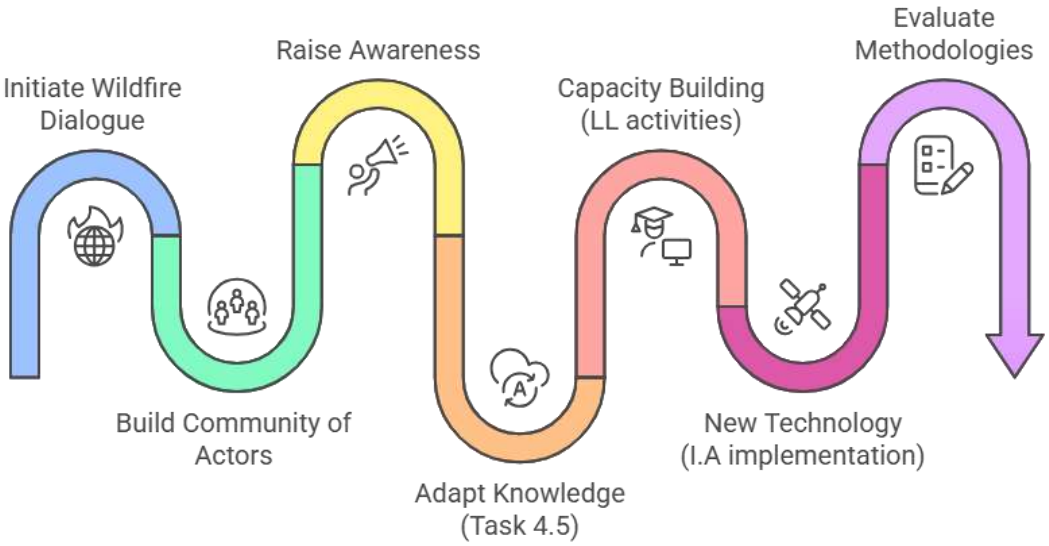

Figure 71: Roadmap of Norway-Sweden LL.

The next steps, until 2030, focus on continuing the collaboration with CWI members to exchange wildfire-related information, foster networking, and work towards achieving resilient landscapes. The aim is to continue raising awareness so that wildfire management is not forgotten and can become a priority. We also aim to prepare for future risk scenarios and initiate the first steps to integrate fire mitigation and resilience measures into public policies and forest management plans.

Apart from the commitment to continuing with the CWI network. Two working groups have been established, consisting of participants from wildfire research institutions and government agencies. One with Swedish and Norwegian partners to work towards the harmonization of the two countries' systems related to wildfires (risk, fuel classes,

models). The other working group have members from Norway, Sweden, and Finland with an aim of collaborate in projects that can continue and expand on the work started in FIRE-RES.

As a result of the training workshop for first responders (WP 4), we have initiated plans for organizing similar training events in Norway-Sweden beyond the end of the FIRE-RES project. A working group has been established with the aim of having such training events connected to SNS Nordic wildfire network.

11.5. CWI feedback (description & involvement)

Since the initial meeting, participants of CWI have highlighted the importance of having a forum for discussing fire-related topics, fostering networking opportunities, and collaboration. 70% express their interest in continuing to attend these meetings to advance wildfire management solutions. They not only showed interest in a discussion forum, but also in having presentations to showcase each other's work and expertise, as well as workshops and more guided discussions.

Table 15: CWI participants.

Entity name	Stakeholder type	Description & Web	Meetings
NIBIO	Academy/ science	Norwegian institute for bioeconomy research https://www.nibio.no/en	1st,2nd,3rd
DSB	Public sector	The Norwegian Directorate for Civil Protection https://www.dsb.no/	1st,2nd,3rd
Midt-Hedmark Fire and Rescue	Society	Fire and Rescue Service https://mhbr.no/	1st,3rd
Södertörn Fire and Rescue Service	Society	Fire and Rescue Service https://www.sbff.se/	1st3rd
Landbruks- og matdepartementet	Public sector	Ministry of Agriculture and Food https://www.regjeringen.no/no/dep/lmd/id627/	1st,2nd,3rd
SLU	Academy/ science	Swedish University of Agricultural Sciences https://www.slu.se/en/	1st
SMHI	Academy/ science	Swedish Meteorological and Hydrological Institute https://www.smhi.se/en	1st
Glommen Mjøsen	Private sector	A forest owners' cooperative https://www.glommen-mjosen.no/	1st
Skogsstyrelsen	Public sector	The Swedish forest agency https://www.skogsstyrelsen.se/en	1st
RISE	Private sector	The research institute of Sweden https://www.ri.se/en	2nd,3rd
SKOGBRAND	Private sector	Norwegian forest insurance company https://www.skogbrand.no/	1st,2nd
MSB	Public sector	Swedish civil contingencies agent	1st,2nd,3rd

		https://www.msb.se/en/	
VIPO	Private sector	Developers of protection products for global markets (thermal, fire, and corrosion) https://www.viposolutions.com/	2nd,3rd
MET	Academy/ science	The Norwegian Meteorological Institute https://www.met.no/	2nd,3rd
Securo	Private sector	Developer of Firebreather® technology https://securonorway.com/	2nd
Bergen brannvesen	Society	Bergen Fire Department City of Bergen - Bergen Fire Department	2nd
Landbruksdirektoratet	Public sector	Directorate of Agriculture https://www.landbruksdirektoratet.no/nb/	2nd,3rd
INCA AB	Private sector	International Carbide Technology for fire safety https://incatech.se/	2nd
Grenland brann og redning	Society	Grenland Fire and Rescue service https://www.gbr.no/	2nd
Høgskulen på Vestlandet	Academy/ science	Western Norway university of applied sciences https://www.hvl.no/en	2nd,3rd
UiT Norges arktiske universitet	Academy/ science	The Artic university of Norway https://en.uit.no/startsida	2nd,3rd
Backegårds	Private sector	Manufacture of wood processing and fire-proof wood products. https://www.backegards.com/	2nd
Jotne Connect	Private sector	Provider of Product Data Solutions https://jotneconnect.com/	2nd,3rd
Den Norske Turistforening	Society	The Norwegian Trekking Association https://www.dnt.no/	2nd
PAU Costa Foundation	Private sector	A Nonprofit organization for forest fire prevention and management https://www.paucostafoundation.org/	3rd

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12. Portugal (PT)

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12.1. Wildfire context

The Portugal Living Lab encompasses two territories with distinct socio-ecological and fire-regime characteristics:

The **Vale do Sousa area** extend over 14316 ha spans six municipalities in Nort-Western Portugal - Felgueiras, Lousada, Paços de Ferreira, Paredes, Penafiel (Porto district), and Castelo de Paiva (Aveiro district) - within the Tâmega e Sousa (NUTS III) region. This densely populated area (~443 inhabitants/km^2) has a dynamic land use mosaic, characterised by intensive forestry (notably eucalyptus), mixed agriculture, and highly interspersed settlement patterns; high economic dependence on the primary sector, and extensive wildland–urban interfaces (WUIs). https://fire-res.eu/living-lab/living-lab-portugal/

The **Lousã area**, located in Coimbra district (Centro region, Pinhal Interior Norte NUTS III), extending over 10,385 ha with a lower population density (123 inhabitants/km^2) and it is characterized by steep slopes forest dominance (~59%), and frequent summer temperatures exceeding 40 °C - conditions that increase its vulnerability to wildfire creating favourable conditions for rapid fire spread (Nunes et al., 2024).

Together, these areas reflect some of the most relevant features of Portugal's wildfire context: dense WUI patterns, fragmented land ownership, high biomass accumulation, and increasing exposure to extreme wildfire events (EWE).

12.1.1. Fire regime, socio-ecological context, and impacts

Over the past 24 years, **Portugal's wildfire regime remained highly active** between 2000 and 2024, data from the Instituto da Conservação da Natureza e das Florestas (ICNF) show consistent annual wildfire activity, with particularly destructive fire seasons occurring in 2003, 2005, 2017, and 2022. These years were marked by extreme meteorological conditions, including heatwaves and drought, leading to megafires that surpassed 100,000 hectares burned in single events. While the number of ignitions has declined over the past decade, burnt area has become increasingly concentrated in short periods under EWE conditions, highlighting a growing decoupling between frequency and severity.

Historical data from 2000 to 2017 indicates consistent fire activity in both regions, Vale do Sousa recorded 463 small fires (<500 ha) and 5 large fires (>500 ha), burning 14,354 ha and 10,059 ha respectively. In the same period, Lousã experienced 58 small fires and

1 large fire, burning 3,652 ha and 4,380 ha respectively. In contrast, during the 2018–2022 period, no large fires were recorded in either region. However, 33 small fires in Vale do Sousa burned 669 ha, while 2 small fires in Lousã burned 9.7 ha, indicating a decline in total burned area but ongoing fire activity.

Wildfire seasonality across both LLs typically peaks from July through September, although early ignitions and dry springs can extend this window. Fire spread is driven by high wind intensity, elevated temperatures, low humidity, and steep terrain. The 2024 fire season, however, re-emphasized that fire behaviour is increasingly influenced by extreme meteorological events, not just traditional seasonality.

Burned Area and Fire Novelty (2023- 2024)

The 2023 fire season saw approximately 3,757 fires across Portugal, with 8,877 hectares burned — 2,811 ha in forests, 5,638 ha in shrublands, and 428 ha in agricultural areas (ICNF;2023). In 2023, the Tâmega e Sousa region, home to the Vale do Sousa Living Lab, experienced 885 wildfires, with most being small-scale fires under 1 hectare in size. Despite their small size, these fires burned a significant total area of approximately 1,838 hectares, distributed across 626 hectares of forest, 1,171 hectares of shrubland, and 41 hectares of agricultural land. In contrast, the Região de Coimbra, which includes the Lousã Living Lab, recorded fewer fires, totalling 279 events, and a much smaller burned area of around 274 hectares, mainly forested land (ICNF's *8th Provisional Rural Fire Report of 2023)*.

According to an early 2024 update from the ***Joint Research Centre (JRC)*** and ***EFFIS***, in 2024, the country recorded 147,461 hectares burned across 735 fires by year-end (San-Miguel-Ayanz et al., 2025). Despite a historic 43% decrease in the number of fires, these figures represent the third highest annual burned area since 2014 (ICNF 2024). Notably, 100,000 hectares were lost within a single week in August 2024, reflecting the growing fire severity and intensity in a warm climate. This included 81, 206 ha of forest, 45,582 ha of shrubland, and 9635 ha of agriculture (ICNF;2024).

https://www.icnf.pt/florestas/gfr/gfrgestaoinformacao/grfrelatorios/areasardidaseocorrencias

This decoupling between ignition frequency and fire extent was especially evident in September 2024, when 1,917 fires (31% of all fires) accounted for 93% of the annual burned area — over 125,999 hectares (ICNF). Among them, 80 large fires (>100 ha) alone caused 93% of the total area burned. These fires ignited under high to extreme fire weather conditions (DSR ≥ 30), often exceeding the suppression capacity of local and regional systems.

According to the ICNF's Final *8th Provisional Rural Fire Report of 2024*, the Tâmega e Sousa region (where the Vale do Sousa Living Lab is located) remained one of the most affected, with 923 fires and 22,407 hectares burned—representing 16% of the total. Of this, 11,236 ha was forest, 9,544 ha shrubland, and 1,627 ha agricultural. Notably, most fires in this region were small in scale, with 84% affecting less than 1 ha, but several high-severity

events continued to contribute significantly to the area burned. Meanwhile, the Região de Coimbra (home to the Lousã Living Lab) recorded a much lower impact, with only 157 fires and 1,473 ha burned, primarily forested zones (1,212 ha). This demonstrates a sharp contrast in wildfire pressure between the two LLs in 2024, possibly influenced by different fuel loads, climate exposure, and land management.

Overall, 2023 and 2024 fire seasons demonstrate a growing divergence between the number of ignitions and the extent of area burned, signalling a shift in fire dynamics. While ignition frequency has decreased, extreme weather events and climate change have amplified fire severity, leading to larger, more destructive fires concentrated in shorter periods. This pattern challenges traditional wildfire management strategies that rely heavily on historical seasonality and fire behaviour assumptions.

In summary, recent fire seasons clearly demonstrate this shift:

- 2023 recorded 8,877 ha burned nationwide, with Vale do Sousa experiencing 885 fires (1,838 ha burned) and Lousã 279 fires (274 ha).
- 2024, however, saw 147,461 ha burned across Portugal - the third-highest since 2014- with over 100,000 ha lost in a single week in August. Vale do Sousa was among the most affected sub-regions (22,407 ha), whereas Lousã recorded far lower impact (1,473 ha).

These patterns underscore strong spatial contrasts between the two LL areas, linked to fuel loads, land-use patterns, climate exposure, and management practices.

Vegetation, WUI Exposure, and Socioeconomic Vulnerability

The two LL PT territories present contrasting yet complementary socio-ecological profiles, **both characterised by high exposure to wildfire**.

- Vale do Sousa combines intensive forestry, small-scale agriculture and dense settlement patterns, resulting in extensive WUI interfaces and high ignition probability.
- Lousã, by contrast, is dominated by contiguous forest and shrubland mosaics, steep terrain and scattered rural communities, creating conditions for rapid fire spread under extreme fire-weather.

In Vale de Sousa, 71% of forests and woodlands are fire-adapted, while in Lousã, only 21% are fire-adapted. The vegetation in Lousã is more susceptible to long-term fire damage. Fire-adapted ecosystems can recover more rapidly and contribute to resilience. Fire-adapted ecosystems include vegetation types that have evolved to withstand or even depend on fire, such as species that resprout after burning, have fire-resistant traits, or rely on heat to trigger seed release.

Vegetation in both areas is primarily composed of eucalyptus plantations, pine forests, and resprouting shrublands, with increasing fuel continuity driven by land abandonment and limited active management. These dynamics contribute to high fuel loads and

persistent accumulations of fine and coarse fuels, particularly in mid- and upper-slope positions around Lousã and in the interstitial forest patches surrounding the urban nuclei of Vale do Sousa.

The Wildland-Urban Interface (WUI) exposure is markedly higher in Vale do Sousa, where dispersed settlements, industrial areas and transport corridors intersect with forested areas, generating multiple ignition points and increasing suppression complexity. **In Lousã, exposure is lower in absolute terms but significant around mountain villages and tourism areas**, where accessibility constraints and steep slopes amplify vulnerability.

Vale de Sousa and Lousã are areas with aggregated wildfire risk ranging between 90-98%. In both regions, 90-95% of people live in WUI areas, zones where human settlements and wildland vegetation intermix. All of them count with a WUI fire risk prevention plan, available at https://www.cm-penafiel.pt/viver/protecao-civil/plano-municipal-de-defesa-da-floresta/ and https://cm-lousa.pt/atividades-municipais/protecao-civil-e-florestas/pmdfci/ for Vale de Sousa and Lousã, respectively.

- **Lousã** spans an area of approximately 138.4 km², with forests occupying about 58.6% (≈81 km²), agricultural land 17.2% (≈24 km²), and urban areas only around 2% (≈2.8 km²) (Nunes et al., 2024). The Wildland–Urban Interface (WUI) in Lousã is significant, with the WUI boundary extending approximately 341.77 km, indicating a high degree of intermix between human settlements and wild vegetation (Nunes et al., 2024).
- In **Vale do Sousa**, 14,316-hectare (~143.2 km²) in the FIRE-RES Living Lab, eucalyptus dominates the landscape, covering 51.8% of the total area, followed by agriculture (16%) and building areas (8.1%). Other land uses include maritime pine (4.1%), shrubland (6.8%), non-riparian zones (7.5%), and riparian zones (2.8%), with bare land and water covering minimal areas.

In Vale do Sousa, WUI areas were identified using the criteria from WP2 deliverables (D2.3, D2.4), following the Federal Register definitions: interface WUI includes areas with ≥3 structures per acre (4046.9 m²) adjacent to wildland vegetation, while intermixed WUI includes scattered housing with a density >1 house per 40 acres (≈6.17 houses/km²) within wildland vegetation (USDA, USDI, Mowery et al.,2019).

Fire prevention plans exist for both areas and are publicly accessible. However, the adoption of buffer zone measures (vegetation clearance, firebreaks) is incomplete, leaving a gap in the data regarding the percentage. Houses are generally built from non-flammable materials (brick, stone, concrete). Approximately 65–68% of GDP in both areas is tied to the primary sector (agriculture, forestry), which is economically vulnerable to fire. High human exposure and economic vulnerability demand stronger WUI mitigation efforts.

Socioeconomic vulnerability, although distinct in each territory, is shaped by convergent structural patterns:

- ✓ fragmented land ownership, particularly acute in Vale do Sousa, limiting coordinated fuel management;
- ✓ aging rural populations, especially in Lousã;
- ✓ declining agricultural activity, reducing landscape multifunctionality;
- ✓ economic dependence on the forestry sector (eucalyptus, resin, biomass);
- ✓ increasing pressure on local emergency services, due to recurrent summer fire peaks.Taken together, these characteristics reinforce the systemic nature of wildfire risk and highlight the need for integrated, multilevel governance and community engagement.

12.1.2. Governance framework

Portugal's wildfire governance framework is structured under the Integrated Rural Fire Management System (SGIFR), **which promotes a risk-based, multi-actor approach spanning prevention, preparedness, emergency response and post-fire recovery** Wildfire governance in Portugal, including the Vale de Sousa and Lousã regions, is informed by the Plano Nacional de Gestão Integrada de Fogos Rurais (PNGIFR), a comprehensive national plan that reflects the country's shift toward integrated and risk-based wildfire management. PNGIFR includes three core components:

Estratégia 2020-2030: A long-term strategy defining Portugal's vision and objectives for wildfire risk reduction.

Cadeia de Processos: A process-based operational framework aligning actions across the wildfire risk management cycle.

Plano Nacional de Ação (PNA): An action plan that specifies implementation measures and responsibilities.

The main objectives of PNGIFR are:

- To reduce loss of human life to the point where fire-related deaths are exceptional;
- To limit the number of fires exceeding 500 ha to no more than 0.3% of all ignitions;
- To restrict total burnt area between 2020 and 2030 to below 660,000 hectares.

These objectives are grounded in Council of Ministers Resolution No. 12/2019, which established the Sistema de Gestão Integrada de Fogos Rurais (SGIFR). This integrated system emphasizes coordinated, cross-sectoral governance, considering fire as an ecological and socio-economic challenge rather than a purely emergency problem. The

PNGIFR strategy reflects elements of transformative resilience (McWethy et al., 2019), particularly in its ambition to shift from reactive suppression to landscape-scale prevention, structural reform, and community co-responsibility. It combines adaptive governance mechanisms with proactive institutional realignment.

Wildfire preparedness involves a coordinated effort among multiple institutions:

- At national level, the system is led by **AGIF (Agência para a Gestão Integrada dos Fogos Rurais) which** coordinates overall public policies and ensures alignment across entities.
- with key roles played by **ICNF (Instituto da Conservação da Natureza e das Florestas) which** manages wildfire prevention and fuel management in rural lands.
- **ANEPC (Autoridade Nacional de Emergência e Proteção Civil)** civil protection and emergency response leads suppression coordination and wildfire prevention in urban areas.
- **GNR (Guarda Nacional Republicana)** plays a key role in **surveillance, detection, and ignition deterrence**, following guidelines from ICNF and ANEPC.
- **ENB (Escola Nacional de Bombeiros)** - training
- **Municipalities** hold increasing responsibilities in local planning, fuel management, public awareness and coordination of local rural fire management units

Local Governance and the Role of Associação Florestal do Vale do Sousa (AFVS)

In the **Vale do Sousa** and **Lousã** territories, wildfire governance involves a wide network of actors operating across administrative and operational levels, including municipalities, intermunicipal communities (douro, Tâmega e Sousa; Região de Coimbra), volunteer fire brigades, forest owners' associations, local industries, environmental NGOs and community groups. These actors interact through planning instruments such as municipal wildfire protection plans, fuel management programmes and community engagement initiatives.

Local governance actors, particularly municipalities, play a critical role in implementing wildfire prevention, preparedness, and protection measures. Each municipality develops a Municipal Plan for the Defense of Forest Against Fires (PMDFCI), aligned with the national strategy but tailored to local conditions. These plans define fuel management zones, evacuation procedures, infrastructure risk assessments, and community awareness activities. Municipal civil protection services coordinate closely with volunteer firefighters, local police, and residents to ensure effective wildfire management https://prociv.gov.pt/pt/anepc/quem-somos/a-autoridade/ , https://diariodarepublica.pt/dr/home

In Vale do Sousa, the **Associação Florestal do Vale do Sousa** (AFVS) is a central actor in wildfire prevention and rural landscape management. AFVS supports landowners with

fuel reduction practices, provides training and technical assistance, and acts as a bridge between public authorities and forest producers. AFVS also engages in community-level planning and monitoring and collaborates with municipalities and the Instituto da Conservação da Natureza e das Florestas (ICNF) to implement fire-resilient landscape strategies. https://www.afvs.ws/apoio-tecnico.html

Key preventive measures include:

- Annual public awareness campaigns, such as Portugal Chama ("Portugal Calls"), which promote self-protection, risk awareness, and safe evacuation planning.
- Community-focused initiatives like "Aldeias Seguras" (Safe Villages) and "Pessoas Seguras" (Safe People) engage local populations in risk reduction and resilience-building efforts.
- Increased patrolling and dissuasive presence by GNR in fire-prone rural and forested zones.

Fire suppression is managed by a multi-layered response system:

- Volunteer firefighter corps constitute the backbone of operational suppression.
- Professional forest sappers and GNR units provide additional capacity, particularly for detection and initial attack.
- ANEPC commands the suppression operations, coordinating aerial assets, field response teams, and inter-agency logistics.

The suppression strategy prioritizes:

- Rapid response and early containment (early attack doctrine)
- Protection of people and built infrastructure
- Simultaneous suppression along multiple flanks where feasible
- Limiting fire spread and total burnt area, especially in WUI contexts

However, the capacity to determine causes of ignition remains limited, which hampers post-event learning and targeted prevention strategies.

Post-fire restoration in Vale de Sousa and Lousã is overseen by ICNF, which is responsible for planning and executing ecological recovery efforts, including reforestation, soil stabilization, and erosion control. However, the penetration of insurance coverage remains critically low:

- Most forests and agricultural lands are uninsured, leaving landowners exposed to catastrophic economic loss.

- WUI homes may be insured, but typically only against internal, accidental ignitions - not external wildfires. This creates a major financial vulnerability for affected households.

Reforestation efforts are primarily state-led, with limited voluntary or private-sector participation. This reflects both low incentives and resource limitations in rural land ownership contexts.

The wildfire governance system in Portugal is evolving toward integrated, risk-based, and resilience-focused approaches, with Vale de Sousa and Lousã representing test cases for this national transition. While strategic coordination and public awareness efforts have expanded, significant challenges remain in ensuring consistent implementation of prevention measures, improving ignition source investigation, and closing economic protection gaps through insurance or incentives. Both LL territories face persistent governance challenges:

- Fragmented land ownership,
- Limited maintenance of fuel management infrastructure,
- Insufficient incentives for active land management,
- and variable engagement of local communities.

These structural issues constrain the implementation of integrated fire management and were repeatedly highlighted by local stakeholders throughout the CWI process.

Future policy should prioritize transformative resilience by combining ecological restoration, community engagement, and institutional innovation to prepare for a changing fire regime under climate and land-use pressures.

12.2. Vision for wildfire-resilient landscapes in 2030

12.2.1. A 2030 wildfire-resilient landscape in Portugal

The Vision 2030 for the Portuguese Living Lab (LL) reflects a **transition towards fire-resilient territories where communities, landowners, institutions and economic actors share responsibility for risk reduction**, sustainable land management and rapid, well-coordinated response under extreme wildfire events. A wildfire-resilient landscape in 2030 is characterized by **multifunctional, biodiverse and actively managed territories**, where forests, agriculture, conservation and recreation coexist in a balanced way. Land management is **professional, collaborative and economically viable**, generating socio-economic value and reinforcing the sense of safety and well-being for present and future communities.

This vision is grounded in **collaborative governance, evidence-based decision-making**, and **landscape management approaches** that enhance ecological resilience, economic

viability and social preparedness. By 2030, the LL PT envisions to consolidate territories that are:

- **Diverse and adapted to climate change**, reducing fuel continuity and moderating fire behaviour;
- **Safer**, through coordinated fuel management, risk-aware spatial planning and strengthened WUI protection;
- **Managed at the appropriate spatial scale**, overcoming the limitations of land fragmentation;
- **More resilient**, supported by multifunctional landscapes, active land stewardship and adaptive forest management;
- **Supported by circular bioeconomy and ecosystem-service markets**, making forests economically relevant and socially valued;
- **Better prepared**, with communities equipped with risk literacy, clear protocols and accessible tools for prevention and self-protection;
- **Connected through an interoperable data infrastructure**, enabling integrated decision-making across all phases of the fire cycle;
- **Operationally integrated**, ensuring agile coordination between municipal, intermunicipal, regional and national actors;
- **Home to engaged communities**, empowered through risk literacy, participation and shared responsibility fostered by initiatives such as the CWI (Community of Wildfire Innovation) under the FIRE-RES project;
- **Innovative**, benefiting from technologies, decision-support systems and training approaches validated during FIRE-RES.

This vision is rooted in the work carried out between 2022 and 2025, particularly in the participatory outcomes of the Challenge Design Workshop (CDW, 2022) and the trajectory of the LL PT throughout the four years of FIRE-RES. It builds on the CWI process, the sustained engagement of local stakeholders, and the field demonstration and validation of Innovation Actions (IAs) aligned with territorial priorities.

12.2.2. Resilience in fire preparedness and prevention

Vision for 2030: Perform fuel management using diversified and collaborative strategies involving different professionals and communities, building happier, healthier and safer communities.

Challenges suggested:

- Promote collaborative wildfire prevention and preparedness activities in the field;
- Improve funding distribution support to small owners;

- Increase communities' acceptance of prescribed burnings;
- Foster different strategies for fuel management other than mechanical treatments, particularly in the WUI areas;
- Increase society's awareness for the need of performing fuel management;
- Foster private owners' willingness to change their WUI territories LULC according to best practices;
- Increase wildfire awareness campaigns for tourists.

12.2.3. Resilience in wildfire emergency management

Vision for 2030: Good detection, effective initial attack and good communication during the event, leading to less wildfires and reducing landscape impacts.

Challenges suggested:

- Improve communication during the wildfire event;
- Improve real-time fire behaviour analysis.

The response system ensures efficient detection, rapid and effective initial attack, and clear communication with all operational actors and communities.

Fire behaviour is monitored in real-time and extreme wildfire dynamics are better anticipated, reducing impacts on people, assets and ecosystems.

12.2.4. Resilience in post-fire management and adaptation

Vision for 2030: Landscape diversity with high biodiversity, promoted by collaborative and professional forest management, supporting multiple-use forests, and creating value, innovation, and will enjoy the forest.

Challenges suggested:

- Generate ecosystem services schemes;
- Foster private owners' willingness to change their territories LULC according to best practices;
- Create socioeconomically viable and bio-businesses to attract new people to the less favoured rural territories;
- Provide hi-tech conditions to promote viable LULC changes according to best practices;
- Increase control actions of invasive plants;
- Increase certified forest areas

12.2.5. Other resilience aspects

None.

12.3. Gaps to reach that vision

Stakeholders identified several structural gaps that hinder progress toward the 2030 vision. These gaps are distributed across all phases of the integrated fire management cycle:

12.3.1. Preparedness phase

Challenge 1 |Fragmented land ownership limiting landscape-scale planning

Thousands of small, dispersed parcels prevent coordinated fuel management, silviculture, and risk-based planning.

Potential solutions:

- Expand cooperative models (e.g., ZIFs, associations, community-based arrangements);
- Develop incentives for shared management and multi-owner interventions;
- Integrate property-level data into municipal and intermunicipal planning tools.

Challenge 2 | Insufficient technical and human capacity at municipal level

Many municipalities, especially smaller ones, lack the resources to maintain prevention plans, monitor WUI areas, and coordinate local operations.

Potential solutions:

- Strengthen intermunicipal technical pools coordinated by CIMs;
- Create shared prevention brigades and operational support teams;
- Introduce stable, multi-annual prevention funding mechanisms.

Challenge 3 | Limited acceptance and understanding of integrated fire management

Limited maintenance of fuel breaks and strategic fuel management zones, reducing long-term effectiveness. Communities still associate fire exclusively with destruction, limiting acceptance of prescribed burning and other risk-reduction tools.

Potential solutions:

- Expand IA4.1 & IA4.2 programmes for risk communication;
- Promote demonstration activities with local brigades and forest owners;
- Develop guidance tailored to WUI residents, schools and tourists.

12.3.2. Prevention phase

Challenge 4 | Narrow reliance on mechanical fuel treatments

Prevention remains overly dependent on mechanical solutions, which are costly and unsustainable at large scale.

Potential solutions:

- Promote diversified strategies: grazing, agroforestry, selective thinning, prescribed fire;
- Create incentive schemes for non-mechanical treatments (PSE, certification, tax reductions);
- Strengthen knowledge exchange on nature-based prevention.

Challenge 5 | Lack of economic incentives for sustainable forest management

Forest management is rarely economically viable for small owners, discouraging prevention investments.

Potential solutions:

- Support the development of ecosystem-service markets (carbon, water, biodiversity, cultural services);
- Encourage bio-based industries that absorb local biomass;
- Promote forest & Fire wine certification in Vale do Sousa and Lousã.

Challenge 6 | Persistent vulnerabilities in WUI areas

Fuel accumulation, unplanned development, and limited maintenance increase community exposure.

Potential solutions:

- Integrate wildfire risk criteria into local land-use plans;
- Promote building-level and property-level protection measures;
- Strengthen enforcement and inspection mechanisms in high-risk WUI zones.

12.3.3. Detection phase

Challenge 7 | Overreliance on human detection and limited integration of new technologies

Although Portugal benefits from vigilant populations, the detection system still lacks sensors, automated alerts, and integrated monitoring.

Potential solutions:

- Expand remote-sensing, fixed cameras, UAV/UAS patrols;

- Integrate detection outputs into shared operational platforms used by agencies;;
- Enhance municipal and intermunicipal monitoring networks.

Challenge 8 | Fragmented detection data and slow integration into operational workflows

Information from watch towers, citizens, meteorology and sensors remains dispersed across agencies. Operational challenges in translating fire-weather intelligence and complex risk indices into actionable, local-level protocols.

Potential solutions:

- Develop a unified detection and risk-information platform (aligned with IA5.7/IA5.9);
- Standardize protocols for rapid data sharing between ICNF, AGIF, municipalities and fire services.

12.3.4. Response phase

Challenge 9 | Difficulty in modelling and anticipating extreme wildfire behaviour (EWE)

Operational prediction tools still struggle to represent extreme events, limiting strategic decision-making.

Potential solutions:

- Expand training programmes on EWE scenarios for all agencies;
- Integrate improved predictive tools (wearables, DSS, fire-spread simulations) into operations;
- Use field exercises to test and refine models.

Challenge 10 | Interoperability gaps between agencies

Decision-making is hindered by fragmented communication and lack of shared situational awareness.

Potential solutions:

- Deploy interoperable digital platforms enabling real-time data exchange;
- Harmonise protocols between ICNF, AGIF, GNR, municipalities and fire brigades;
- Conduct regular joint drills at municipal and regional scales.

Challenge 11 | Community engagement during emergencies remains fragile

Trust between fire services and the population can break down under pressure, affecting evacuation readiness.

Potential solutions:

- Develop clear, locally adapted self-protection plans;
- Improve communication channels during events (apps, messages, sirens, local hubs);
- Promote community-based emergency training.

12.3.5. Restoration and adaptation phases

Challenge 12 | Limited post-fire restoration planning

Delays in decision-making and bureaucratic constraints worsen soil erosion, invasive species spread and loss of regeneration post-fire action remain reactive, with uneven integration of ecological principles.

Potential solutions:

- Pre-plan restoration strategies for priority areas;
- Create rapid-response ecological restoration teams;
- Streamline administrative procedures for emergency silviculture.

Challenge 13 | Fragmented land ownership prevents large-scale restoration

Post-fire mosaics cannot be implemented effectively when owners act individually.

Potential solutions:

- Promote joint-owner recovery programmes;
- Enable multi-owner agreements for restoration at watershed or landscape level;
- Integrate post-fire actions in ZIF and AIGP processes.

Challenge 14 | Lack of long-term indicators and monitoring

There is no consistent set of quantitative indicators for tracking regeneration, soil protection or fuel re-accumulation.

Potential solutions:

- Establish a monitoring protocol aligned with WP2/WP3 methodologies;
- Integrate remote-sensing, field sampling and citizen science;
- Report results regularly to municipalities and CWI members.

Challenge 15 | Insufficient communication and social support post-fire

Affected communities may misunderstand management decisions or lack psychological support. Lack of continuity between emergency response and post-fire land-use decisions, weakening adaptive capacity.

Potential solutions:

- Improve communication on restoration rationale and expected timelines;
- Integrate social support services into post-fire recovery;
- Provide clearer guidelines to owners on sustainable post-fire management.

>> Cross-cutting operational challenges

Funding

- Prevention and restoration depend on short-term or project-based funding.
- Lack of multi-annual budgeting limits continuity.

Solution: create stable national/regional funding lines; support PSE, certification, cooperative management and digital transformation.

Cross-stakeholder coordination

- Competences are dispersed; collaboration is inconsistent.

Solution: institutionalize the CWI as a long-term multi-actor platform; develop shared governance protocols.

Integration between phases

- Preparedness, response and recovery are often disconnected.

Solution: embed "IFM logic" across all planning instruments; develop integrated municipal plans linking prevention, operations and restoration.

12.4. Steps and milestones: the roadmap

12.4.1. Progress achieved during the project (at CWI level)

Between 2022 and 2025, the Portuguese Living Lab (LL) played an active and mobilising role within FIRE-RES, engaging multiple actors across the territory and consistently driving collaboration, field implementation and innovation. Over this period, it carried out 60 activities, tested over 25 (IAs) - 15 of them implemented directly in the PT LL - and engaged more than 300 participants from around 70 organisations. The LL PT work integrated scientific, operational, policy and community-based perspectives, contributing

significantly to the development, testing and validation of FIRE-RES solutions across the entire fire management cycle.

CWI Pré-meetings Vale de Sousa (October 21, 2022) & Lousã (October 24, 2022)

1st CWI meeting (November 4, 2022 - Lousã)

The first joint meeting of the Vale de Sousa and Lousã Living Labs marked the formal creation of the **Portuguese CWI**. For the first time, local, regional and national stakeholders met under a common forum to initiate a shared vision for wildfire-resilient landscapes.

The meeting built on two preparatory **IFM** sessions held earlier that month (Vale do Sousa on 21 October and Lousã on 24 October), where the FIRE-RES objectives and the set of IAs planned for each LL were first introduced (Figure 72).

Figure 72: Results of the IFM ice-breaker activity carried out in the pre-meetings and 1st CWI meeting of PT LL

Each participant received a postcard with one of 15 landscape photographs and was invited to write a short reflection describing their vision of a *resilient landscape in 2030*. These postcards became the analytical and symbolic foundation for the joint LL PT Vision 2030 and were later used in the dynamic exercise "***Train Through a Resilient Landscape***" (Figure 73).