WUI guideline for Norway

Veileder for å beskytte bebyggelse mot skogbrann i Norge

RISE REPORT 2025:23

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Table of contents

Executive Summary **3**
Sammendrag **4**
Preface **5**
1 Introduction **6**
1.1 Norwegian WUIs and WUI guidelines 6
1.2 The TREEADS project 7
1.3 The Norwegian pilot of TREEADS 7
1.4 Scope and limitations 8
1.5 Method 9
1.6 Ethical aspects 9
2 Key components of the guideline **10**
2.1 Case studies of past fires 10
2.2 Characterisation of wildfires by field experiments 14
2.3 Characterization of natural fuels in the laboratory 15
2.4 Fire-Treated Wood: Resistance to Wildfire Exposure 17
2.5 Study of WUI guidelines from other countries 19
2.6 Stakeholder engagement to refine recommendations 20
3 Main recommendations | Hovedanbefalinger **21**
3.1 Recommendation 1 | Anbefaling 1 21
3.2 Recommendation 2 | Anbefaling 2 22
3.3 Recommendation 3 | Anbefaling 3 23
3.4 Recommendation 4 | Anbefaling 4 23
3.5 Recommendation 5 | Anbefaling 5 24
3.6 Recommendation/anbefaling 6 24
4 Supplementary recommendations | Tilleggsanbefalinger **25**
4.1 Supplementary recommendation 1 | Tilleggsanbefaling 1 25
4.2 Supplementary recommendation 2 | Tilleggsanbefaling 2 25
4.3 Supplementary recommendation 3 | Tilleggsanbefaling 3 26
4.4 Supplementary recommendation 4 | Tilleggsanbefaling 4 26
4.5 Supplementary recommendation 5 | Tilleggsanbefaling 5 26
5 Recommendations that are not included **27**
5.1 Recommendation not included 1 27
5.2 Recommendation not included 2 27
5.3 Recommendation not included 3 27
6 Conclusions **28**
References **29**

Executive Summary

WUI guideline for Norway

Norway is a long country where forests, grass, and heather cover vast areas. Approximately 38% of the country's land area consists of forests, and many structures are located near or surrounded by nature. In these wildland-urban-interface (WUI) areas, a wildfire could damage structures and infrastructure. Norway's tradition of constructing houses and cabins from timber adds an extra layer of vulnerability in WUI areas.

As part of the EU-funded research and innovation project TREEADS, Norway's first WUI guideline has been developed to strengthen resilience against wildfires. The guideline is targeted at citizens in WUI areas, and presents measures that may protect built areas from wildfires.

The development of the guide is based on an extensive process, including a literature review of WUI guidelines from countries such as the USA, Canada, and Sweden. This review formed the foundation for a list of relevant topics and recommendations, which were further refined through in-person workshops with stakeholders, surveys, and expert consultations. To ensure relevance for Norwegian conditions, the recommendations were adapted to local building traditions and by using insights from past fire incidents, fieldwork, and laboratory experiments. This process resulted in six main recommendations (see illustration below) and five supplementary recommendations (given in this report).

Keywords: Wildland-urban-interface, WUI, Norwegian conditions, wildfire, guideline

Sammendrag

Veileder for å beskytte bebyggelse mot skogbrann i Norge

Norge er et langstrakt land der skog, gress og lyngheier dekker store områder. Omtrent 38 % av landets areal består av skog, og mange bygninger ligger i nærheten av eller er omkranset av natur. I denne randsonen mellom natur og bebyggelse, kjent som Wildland-Urban Interface (WUI), vil en skogbrann eller annen naturbrann kunne gjøre skade på bygninger og infrastruktur. Det at Norge har en tradisjon for å bygge hus og hytter i trematerialer utgjør en ekstra sårbarhet i den norske randsonen.

I det EU-finansierte forsknings- og innovasjonsprosjektet TREEADS er Norges første randsoneveileder utviklet for å styrke motstandsdyktigheten mot naturbranner. Veilederen er rettet mot innbyggere i randsonen mellom natur og bebyggelse og gir konkrete tiltak for hvordan man kan beskytte bebyggelse mot naturbranner.

Utviklingen av veilederen bygger på en omfattende prosess som inkluderer en litteraturgjennomgang av WUI-anbefalinger fra land som USA, Canada og Sverige. Dette dannet grunnlaget for en liste over relevante temaer og anbefalinger, som videre ble utviklet gjennom fysiske arbeidsmøter med interessenter, spørreundersøkelser og ekspertkonsultasjoner. For å sikre relevans for norske forhold ble anbefalingene tilpasset nasjonale byggetradisjoner og erfaringer fra tidligere branner, feltarbeid og laboratorieeksperimenter. Prosessen resulterte i seks hovedanbefalinger (se illustrasjon under) og fem tilleggsanbefalinger (angitt i denne rapporten).

Nøkkelord: Randsoner, norske forhold, skogbrann, naturbrann, veileder

Preface

This WUI guideline is a result of the TREEADS project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036926.

The development of the guideline is led by RISE Fire Research in Norway, with valuable input from the partners in the Norwegian pilot in TREEADS, Jotne Connect AS, Woodify AS, Vipo AS, Backegårds List AB, and RISE Research Institutes of Sweden. We would like to extend our gratitude also to all involved stakeholders in the project, for their contribution to the guideline and for ensuring that the guideline is relevant for Norwegian conditions. We are particularly grateful for the collaboration with the Directorate for Civil Protection (DSB) on the development and final publication of the guideline.

The guideline is based on input from many different activities in TREEADS. We are very grateful for the contributions from and discussions with the following: Kvam Fire and Rescue Service, Bergen Fire Service, Grenland Fire and Rescue Service, Fosen Fire and Rescue Service, and West Fire and Rescue Region. We are also grateful for student contributions from Anette Mauno Torbjørnsdatter at UiT The Arctic University of Norway, Magne Rosnes at the Norwegian University of Science and Technology NTNU, as well as Konstantin Motschmann and Maximilian Weisbecker at the Otto von Guericke University Magdeburg OVGU.

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Trondheim, April 2025

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1 Introduction

1.1 Norwegian WUIs and WUI guidelines

Climate change, shifts in land use, and population growth are making wildfires and wildland-urban interface (WUI) fires more frequent and intense, while also affecting larger areas. In Norway, wildfires have been less common than in southern Europe, but with climate change and a growing population, they are expected to become more frequent and severe, reflecting global patterns. As cities and towns expand into wildlands, WUI areas become more exposed to fire risks, creating serious challenges for safety and coexistence. [1–6]

In Norway, both interface WUIs and intermix WUIs are common (Figure 1-1). Norway is a long country where forests, grass, and heather cover vast areas. Many of the larger cities and towns in Norway are surrounded by nature, that is, having interface WUIs and in some cases also intermixed WUIs. Approximately 38% of the country's land area consists of forests [7], and about 20% of the population in Norway per 2024 lives in sparsely populated areas [8]. In addition to residential buildings, Norway has a strong tradition in the use of cabins or holiday homes (in Norwegian "hytte"), with 451 181 cabins per February 2025, which corresponds to about 10% of the total number of structures in the country [9]. Both residential buildings in sparsely populated areas and cabins are often located near or surrounded by nature. In total, this gives extensive interface and intermixed WUIs in Norway. Here, a wildfire could damage structures and infrastructure. Norway's tradition of constructing houses and cabins from timber adds an extra layer of vulnerability in the WUI areas.

Figure 1-1: Two types of wildland-urban-interfaces. Interface WUI (top), where structures are adjacent to the wildland vegetation. Intermix WUI (bottom), where structures intermingle with wildland vegetation. Illustration: RISE Fire Research/ TREEADS.

It should be noted that traditional WUI definitions may not be entirely suitable for Norway's landscapes and settlement patterns, as they often fail to account for the widespread distribution of cabins, the high proportion of forested land, and the scattered nature of rural settlements, as highlighted in a recent study by Medina et.al. [10]. They propose refined definitions of WUIs tailored to the contexts of Norway and Sweden, better capturing the characteristics of WUI areas in these countries. The term "vegetation fires damaging structures" may be more precise than WUI, and we have used this in our case analysis (section 2.1). However, for the majority of this study, we have chosen to use “WUI fires” as a generic term, as it is a widely recognized term internationally.

To reduce vulnerabilities and enhance community safety in WUI areas, several WUI guidelines have been developed around the world (details in section 2.5). These guidelines outline actions that citizens can take to lower the chances of wildfires spreading to their homes, such as maintaining defensible spaces, using fire-resistant materials, and properly managing vegetation. A WUI guideline created for one region may contain elements relevant also for other areas, but local adaptations to specific climate conditions, vegetation, and building practices are important to ensure relevance and adaptation in local communities.

In this report, the first WUI guideline developed specifically for Norway is presented. This guideline has been developed between 2022 and 2025 as part of the Norwegian pilot of the TREEADS project. The recommendations in this guideline use input from guidelines developed around the world and focus on Norway’s specific context and challenges. The guideline is targeted at citizens in WUI areas, and presents measures they can take to protect built areas from wildfires.

1.2 The TREEADS project

The TREEADS project, funded by the EU Horizon 2020 research and innovation program (grant agreement No. 101036926), addresses critical challenges posed by wildfires through the development of a holistic Fire Management Ecosystem. This ecosystem integrates state-of-the-art technologies and cutting-edge research to enhance the management of wildfires across three key phases: prevention and preparedness, detection and response, and recovery and adaptation. With a diverse consortium of 49 organizations, TREEADS combines technical and business expertise to create adaptable solutions that promote sustainable development and resilience for both natural environments and local communities. The project includes eight pilot sites across Europe and Taiwan and is coordinated by RISE Fire Research in Norway.

Resources: Link to the TREEADS project website: https://treeads-project.eu/

1.3 The Norwegian pilot of TREEADS

In the Norwegian pilot of TREEADS the focus is on wildfires in Northern Europe, more specifically in Scandinavia and Norway. The pilot has developed and demonstrated technologies focusing on WUI areas in Norway for all three phases of a wildfire: prevention, response, and adaptation.

An overview of the pilot activities and their connections is given in Figure 1-2. In the pilot, wildfires in Norwegian forests and coastal heather lands have been characterized using field measurements, laboratory studies, and information from past fires [11,12]. Secondly, to reduce vulnerabilities in WUI areas, pilot partners have developed cost-effective fire resilient wooden façade and rubber materials to protect structures and infrastructure. A test method has been developed to document their fire performance when exposed to a Norwegian wildfire [13]. Thirdly, during a wildfire, it can be critical to know the type and location of assets, such as personnel or equipment. To optimize resource allocation, data standardization using ISO 10303 has been used to study how to streamline logistics during wildfire response. Finally, a pilot location has been used to demonstrate the reforestation of burnt areas by the use of seed balls of birch and pine trees that have been adapted to Norwegian conditions and designed to be dropped from drones. Many of the different activities in the pilot have contributed to knowledge that has been used in the development of the guidelines presented in this report.

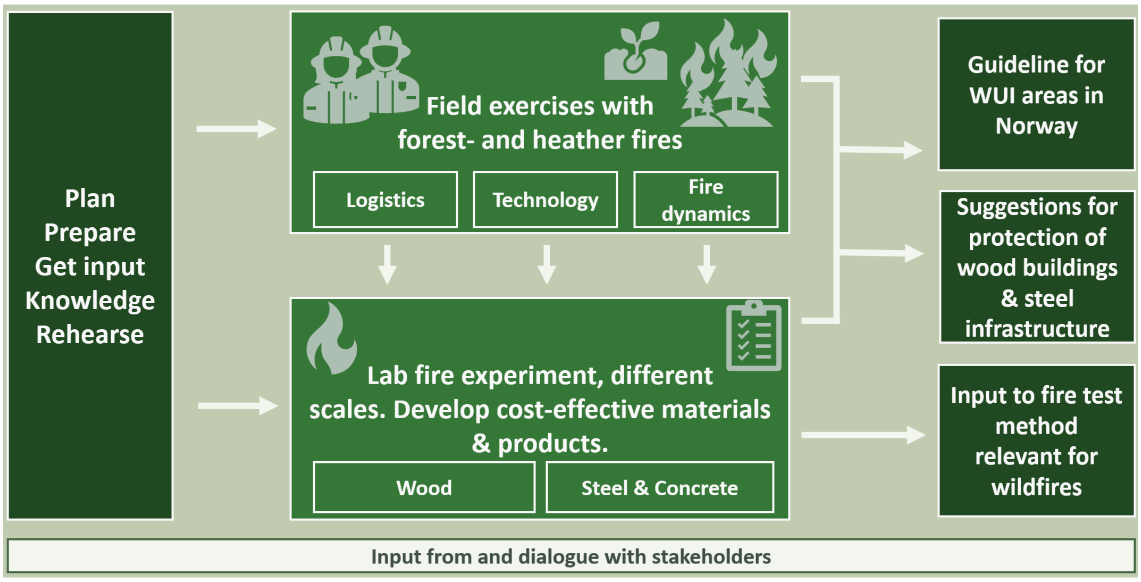


Figure 1-2: Overview of the activities in the Norwegian pilot in TREEADS. In this report, the output "Guideline for WUI areas in Norway" is presented.

Resources: More information on the Norwegian pilot in TREEADS can be found here:

Pilot introduction video (4 min): https://youtu.be/RTc8d8if5UM?si=11PckeunlyQDGHVX

Pilot short video (30 sec): https://youtu.be/qhcQf0SBY8Y?si=L_yW7F7cWeYPyo1T

Reports D4.6 on fire resilient materials, D6.3 on replanting technology, and D8.3 on all activities in the pilot will be available here, once published: https://treeads-project.eu/resources/deliverables/

1.4 Scope and limitations

This guideline focuses on preventing damage to structures in WUI areas in Norway. It emphasizes proactive measures that can be taken well in advance, rather than addressing actions during an active wildfire.

The recommendations are targeted at the citizens, and measures on a community level that require the involvement of the public sector, industry, or others are therefore not in focus.

The recommendations are chosen and formulated considering Norwegian conditions, including natural landscapes, wildfire dynamics, and building traditions. As these factors can be similar for regions in other Nordic countries, the recommendations may also be relevant for people living in WUI areas in other Nordic countries.

The numbering of the recommendations serves solely as a reference and holds no significance in terms of priority.

The recommendations outlined in this report are intended as advice on measures to enhance fire safety in WUI areas and should not be considered a substitute for legally required fire safety measures, such as smoke detectors, fire extinguishing equipment, and stove guards.

1.5 Method

This study employed a mixed-methods approach, combining:

- Analysis of fire incident data in Norway to understand common fire spread mechanisms and to collect other relevant information.
- Participation in field exercises to study prescribed burns and wildfire behavior in Norwegian landscapes.
- Laboratory experiments to assess reaction to fire properties of construction materials and the cavity effect in façade constructions.
- Laboratory experiments to assess fire hazards of natural fuels.
- Literature review of international guidelines and Norwegian-specific conditions.
- Stakeholder engagement through workshops and surveys to refine recommendations.

1.6 Ethical aspects

All inputs and efforts given to the development of this guideline are done in accordance with the General Data Protection Regulation (GDPR) regulations and internal ethics rules of the TREEADS project.

2 Key components of the guideline

This chapter describes the individual activities conducted in the Norwegian pilot of TREEADS and the results that have been key components in the development of the recommendations given in Chapter 3 and 4.

2.1 Case studies of past fires

To understand the characteristics of wildfires in Norway and their impact on residential areas, an analysis was made of recent WUI fires and selected wildfires in Norway.

The study utilized the national fire incident database, BRIS, to identify fires that started in outdoor settings, such as fields and forests, and spread to structures (e.g., houses, garages, commercial buildings, and other buildings). Between January 2016 and March 2023, 74 such incidents were identified. The database provided information on the date, municipality, and involved fire service for each incident. Two types of vegetation fires are defined in the database, grass/cultivated vegetation and forest/uncultivated vegetation[1]. The database does not contain information on the cause of the fire. The results show that springtime (March to May) is a high hazard period for fires in the WUI in Norway (Figure 2-1, left). About 75 % of all the recorded fires that affected structures occurred in this period. The fires were spread throughout the entire country; however, the database does not provide specific information on the exact locations of each fire. As a result, a detailed evaluation of fire locations in terms of vegetation type, rurality, and other factors was not feasible.

The 19 fires that affected two or more structures were studied in detail. The relevant fire services were contacted via email or phone call to provide further information specific to the incidents, such as the mechanism of structure ignition. In particular, we wanted to find information on which of the three main modes of fire spread (illustrated in Figure 1-2) caused the first ignition of the structure in each case. The results indicated that direct flame contact was the main known spread mechanism (Figure 2-1, right). In one case, a building was saved by the presence of a low stone foundation that hindered flame contact. Fire spread by glowing embers was scarce, and only confirmed in 1 out of the 19 cases. Full details from the study, including details on each of the 19 fires, are presented in a journal paper by Mikalsen, Aamodt et.al. [11].

The findings are in line with literature from Sweden that also shows that Scandinavian countries experience fewer crown fires compared to e.g. California, Canada, or Australia. Instead, most fires in Scandinavia are ground-level or grass fires that spread at a slower rate. When spreading to structures, also in Sweden, direct flame contact is the primary mode of flame spread [15]. The Swedish team proposes that the garden structure plays a critical role in survival of structures during wildfires in Scandinavia [15]. The Swedish studies also highlight the importance of reducing flammable vegetation and potential ignition sources, such as forestry machinery, which has been identified as a significant cause of fire ignition. The Swedish studies also highlight fires during springtime as a particular challenge [15–17].

[1] Grass/cultivated vegetation, in Norwegian “Brann i gress- eller innmark”.
Forest/uncultivated vegetation, in Norwegian “Brann i skog- eller utmark”.

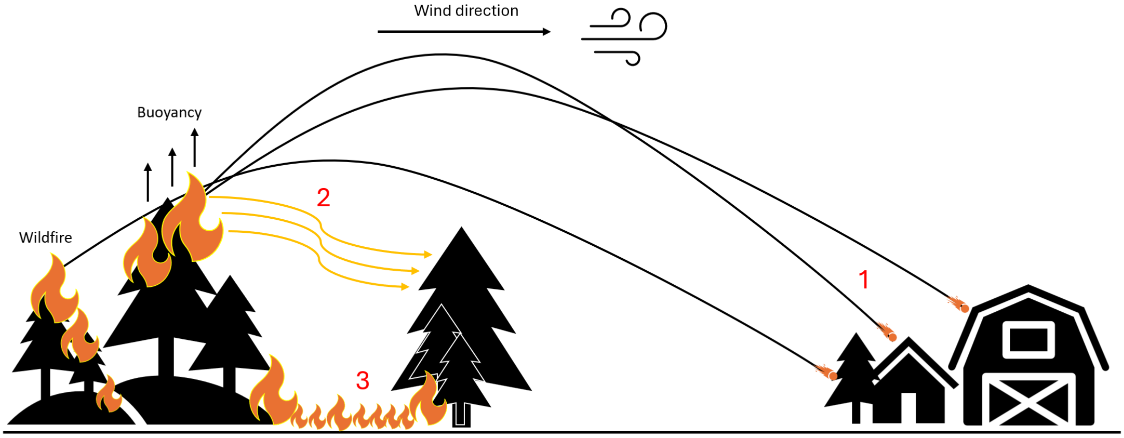
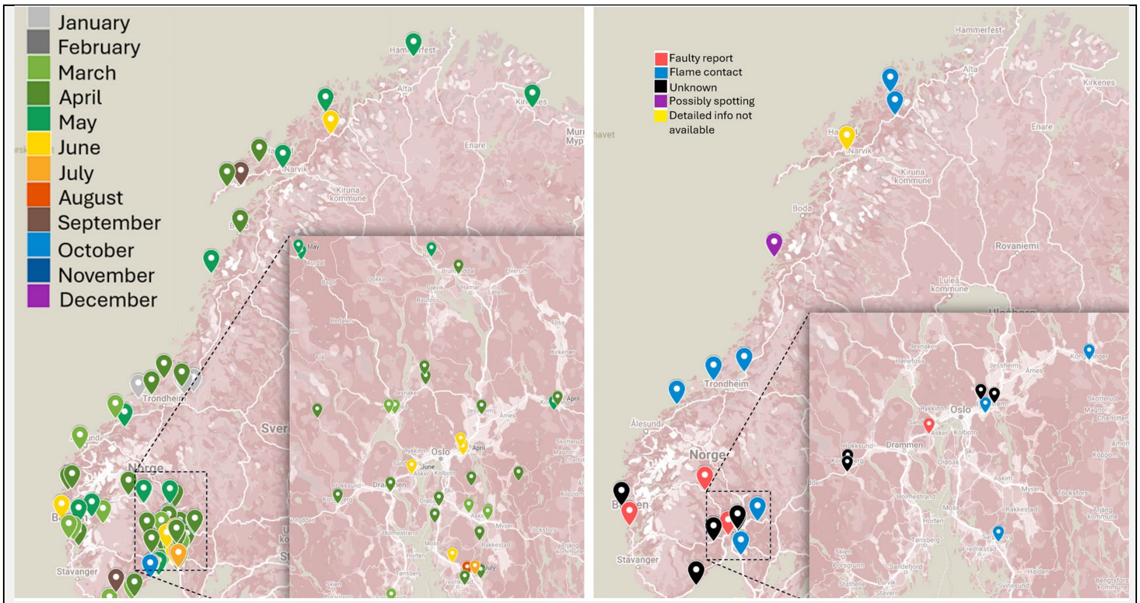


Figure 2-1: Illustration of the three wildfire spread modes. 1) Firebrands or flying burning/glowing embers, also called spotting. 2) Fire spread by radiation. 3) Direct flame contact. Illustration by RISE Fire Research/ TREEADS, inspired by [14].



Online, interactive maps:
Left map: https://www.google.com/maps/d/u/0/edit?mid=1-mP3eTyHiHiD4vdFbZ-lcKizJQRoVQU&usp=sharing.
Right map: https://www.google.com/maps/d/u/0/edit?mid=1xCVLGXDtmZ_WgEpTxlWmPQiW9SiI3Rk&usp=sharing

Figure 2-2: Maps of vegetation fires in Norway during 2016-2023 that damaged buildings or other structures. The locations are approximate on the municipality level. Left: Month of the year for all 74 fires damaging 1 or more structures. Right: Fire spread mode of the 19 fires damaging 2 or more structures. Maps Data: Google, @2024 GeoBasis-DE/BKG (@2009).

A selected set of past fires were also studied to further understand the characteristics of Norwegian wildfires and ignition modes for WUI fires. The 2014 winter fires at Lærdal, Flatanger, and Frøya represented three of the largest fires in Norway in recent times, and they all occurred during an 11 day period in January [18–22]. Literature from the fires showed that strong winds and dry weather periods can give surprisingly intense fires. The fact that the fires occurred during the winter season was also unexpected. The Lærdal fire was first, which was not a wildfire, but a fire starting in a structure and spreading mainly by flying, burning embers from structure to structure, damaging 40 structures, thereof 17 residential homes. The Flatanger fire started a week later (Figure 2-2), where a power line ignited grass and spread through the coastal grass- and heather vegetation. In the Flatanger fire, 63 structures were lost, thereof 23 residential buildings or cabins, which is the largest WUI fire in Norway to date. Only 2 days after the Flatanger fire, a fire started at the coastal island of Frøya, which spread through the coastal vegetation, damaging one structure and a 10 km^2 area. No lives were lost in the 2014 winter fires, but the fires were large in a Norwegian context in terms of complexity and scale.

Some key learning points were extracted from the study of these fires, for the development of this WUI guideline. In the Lærdal fire, strong winds carried glowing embers from one structure to others, entering cavities, eaves, and gaps in the roofs. This caused smoldering of the wooden construction materials and ultimately ignited entire structures [21]. This shows the importance of reducing the amount and sizes of places where embers may lodge and smoulder, in case of fire spread by flying embers (recommendation 6). The Flatanger and Frøya fires demonstrated that, despite having limited fuel from grass and heather in coastal regions, intense and rapid fire spread can still occur under certain conditions, in this case, dry vegetation, and strong winds.

Figure 2-3: Aftermath of the Flatanger winter wildfire of 2014, in which 63 structures were lost - the largest WUI fire in Norway to date. Left photo: Office of the Prime Minister/ Statsministerens kontor (via Flickr, CC BY-ND 2.0). Right photo: Gjensidige (CC BY).

Flatanger and Frøya represent typical Norwegian coastal landscapes, with limited fuel available (mostly grass and heather vegetation). Still, the winter fires here showed that even with a limited amount of fuel available, the right conditions with try vegetation and strong winds may still give intense and rapid fire spread. At Flatanger, many structures were destroyed, but some remained intact after the fire (Figure 2-2). This raises the question, was this a matter of chance, or were there specific protective measures that contributed to their survival?

While this study does not explore that question in detail for the Flatanger case, insights from other large fire events indicate that proactive measures taken by homeowners can enhance the likelihood of a structure's survival. In Lærdal, a single house was left undamaged in the street of Kyrkjeteigen, where the fire spread rapidly during the early phases of the fire (Figure 2-3 left). During the fire, active firefighting measures using water sprays were used to prevent ignition of the structure. In addition, the homeowner had recently renovated the structure, which included closing cavities where embers could lodge and smoulder (Figure 2-3 right). [21]

Figure 2-4: Left: Aftermath of the large fire in Lærdal of 2014, with yellow arrows showing the direction of fire spread, based on information of the fire spread in [21]. A yellow circle is added to mark the house that survived the fire. Right: This house had recently undergone renovations, in which cavities under the roof shingles were closed (arrow). Notice that the roof eaves are horizontal and closed, preventing embers from lodging. Left photo: Jan Christian Jerving, taken from NRK, https://www.nrk.no/vestland/to-ar-sidan-brannen-i-laerdal-1.12751469, used with permission from photographer and NRK. Right photo: RISE Fire Research, taken from [21] with permission.

A similar case was seen in the large fire in Maui, Hawaii, in August 2023 (Figure 2-4), where a single house remained undamaged. According to the BBC [23], this was due to several key factors: it was built using fire-resistant materials, including a metal roof and non-flammable siding, which helped to prevent ignition. Additionally, the homeowners had taken proactive measures, such as creating a defensible space by clearing vegetation around the property, reducing fuel sources for the fire. This case serves as an example that the recommendations outlined in this guideline - particularly recommendations 1, 3, and 4 - can be effective in preventing fire spread.

Figure 2-5: Aftermath of the Maui fires of August 2023, showing that some structures may survive in the midst of a fire blaze due to proactive measures taken by homeowners. Photo: Kevin Fujii/Civil Beat/2023, used under a commercial license, taken from https://www.civilbeat.org/2023/12/the-maui-fires-in-photos-august-2023/.

Finally, to complement these case studies, we visited Roan in the Trøndelag region in Norway after a coastal wildfire in November 2022 [24]. This was a rare case of a winter wildfire, which in its initial phase resembled the 2014 winter fires described above (Figure 2-5 left).
Fortunately, escalation to the 2014 levels was avoided, due to tactical and technical measures, as

well as favourable changes in the weather. The coastal vegetation consisted of intermediate-sized pine and birch trees, juniper bush, grass, heather, as well as large, planted spruce. The area was hilly with an intermix WUI of scattered wooden structures, as well as telecommunication and power lines. A post-fire inspection (Figure 2-5, right) showed that the fire burned about 6 hectares, mostly superficially (0.5–1 cm deep), with some deeper spots (~10 cm) still smoldering several days after flame-out. Burn heights reached 0.5–1 m on hillsides, 1–2 m in the valley, and up to 4–5 m near large junipers. This exemplifies the intense fire development that junipers can exhibit, posing a risk to nearby structures. This underscores recommendation 3, which explicitly advises the removal of large junipers near structures. In the Roan case, no structures were lost to the fire, but it serves as an example of a wildfire in a rural area in Norway, where distances can be great and firefighting resources may be limited. If, e.g., wooden cabins surrounded by nature have implemented measures to create defensible spaces around them (recommendation 3), firefighting efforts can be directed toward other concerns, which would benefit the response.

Figure 2-6: The Roan coastal winter wildfire of November 2022 during the fire (left) and after the fire (right). Photos by RISE Fire Research/ TREEADS, taken from [24] with permission.

2.2 Characterisation of wildfires by field experiments

To better understand wildfire hazards in WUI areas in Norway, the Norwegian pilot of the TREEADS project involved fieldwork through participation in several wildfire exercises organized by local fire services. These exercises were conducted in coastal heathlands of the Atlantic biogeographic area and in drained bogs of the boreal biogeographic area. Along with standardized laboratory experiments (section 2.4), the fieldwork aimed to assess the unique conditions and behaviors relevant to wildfires in Norway. More detail on the locations, measurements, and results may be found in [11]. Two key observations from these field exercises were particularly important in the development of this guideline.

Firstly, the field exercises underscored some key factors influencing fire spread, including vegetation type, moisture content, and weather conditions. Dry vegetation promotes faster fire spread, while high moisture content helps slow it down. Weather, especially strong winds, also plays a significant role in accelerating fire spread. These are conditions that may arise during winters with little snow, and in the spring, before vegetation fully emerges. Spring fires are therefore explicitly mentioned in recommendation 5. This guideline should be available for the public at all times, with spring and autumn being particularly suitable periods for reminders.

Secondly, an important finding from the field exercises was the key role of juniper bushes had in the fire development. This was in line with previous studies suggesting that juniper may be "ladder species" [25], in which the juniper's height combined with an intense fire development can enable a wildfire to move from the forest floor to tree canopies. Figure 2-6 shows a series of photos where a ground fire spread to a juniper bush, which in turn ignited a large tree. This photo series was taken in a fire exercise in a drained bog area, located in the boreal biogeographic region of Norway. This gave input to recommendation 3, and underscored the need to explicitly mention juniper as a high-hazard species in the Norwegian context.

Figure 2-7: The development of a ground fire turning into a crown fire, with juniper being a ladder species, allowing the fire to climb to the tree. The fire spread along grass and heather on the forest floor (left), igniting a juniper bush (middle) and, from there, spreading to a large tree (right). Photo: RISE Fire Research/TREEADS.

2.3 Characterization of natural fuels in the laboratory

Using small-scale experiments, we explored the fire characteristics of five common wildland vegetation species in Norway: stair-step moss, lingonberry shrub, juniper, bilberry branches and stems, and heather (Figure 2-7). The reaction to fire properties were studied using the cone calorimeter (ISO 5660) [26]. The samples were conditioned to similar moisture levels. Results revealed that stair-step moss and bilberry stems had longer burn durations and lower peak heat release rates, indicating slower, more sustained combustion. Heather, regardless of age, exhibited consistent fire behavior, highlighting the importance of moisture content in wildfire dynamics. Evergreens, particularly juniper, showed more intense fire behavior.

For this guideline, three key learning points can be extracted from the study. Firstly, stair-step moss was identified as a potential hazard species for wildfire spread along the forest floor, as it ignited easily and had long burning times. Secondly, the study underlined that older heather is associated with a higher wildfire hazard than fresh, green heather. Thirdly, when combining results on fire behaviour with knowledge of how the species grow in nature, juniper was again found to be a species to have a particular focus on.

Details from the study, including fuels, method, and results may be found in [12] and in the master thesis by Rosnes [27].

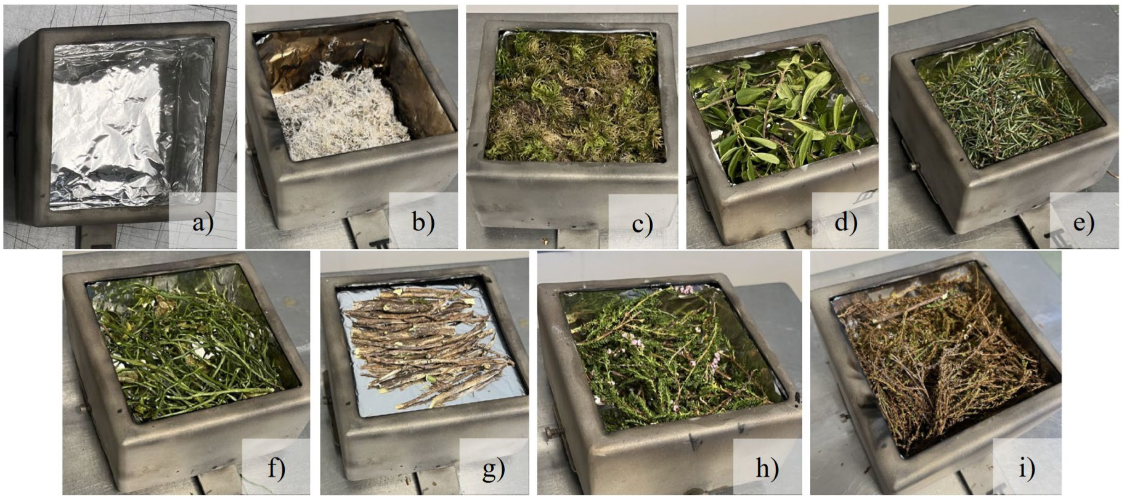


Figure 2-8: Natural vegetation samples from Norway studied using the cone calorimeter. a) Aluminium sample holder before and b) after an experiment, and with c) stair-step moss, d) lingonberry shrub, e) juniper, f) bilberry branch, g) bilberry stem, h) green heather, i) brown heather. Figure by RISE Fire Research/TREEADS, taken from [12], with permission from the authors.

The ladder effect of juniper described in section 2.2 was also demonstrated in the lab. A larger-scale (2x4 meters) test set-up described in [13] was used. The fuel used was ca. 8-10 cm height wood fibre, imitating a fire in a low and dry grassland. Fresh juniper bushes of 50-80 cm in height were mounted vertically in the fuel bed. Figure 2-9 shows the development of a fire along the horizontal fuel bed. The flame length increased from ca. 50-100 cm when only wood fibre was burning to over 2-3 m when the juniper bushes ignited.

The laboratory experiments also demonstrated the difference between a fire spreading along a flat surface and a fire spreading uphill (Figure 2-10). When introducing a 20 degree tilt to the larger-scale set-up, the fire became drastically more intense, with an increased rate of fire spread (4-5 times faster), increased flame length, and fire intensity. This demonstration was made not using natural fuels, but with wood fibre, and the results are in line with the literature (see details in [13]).

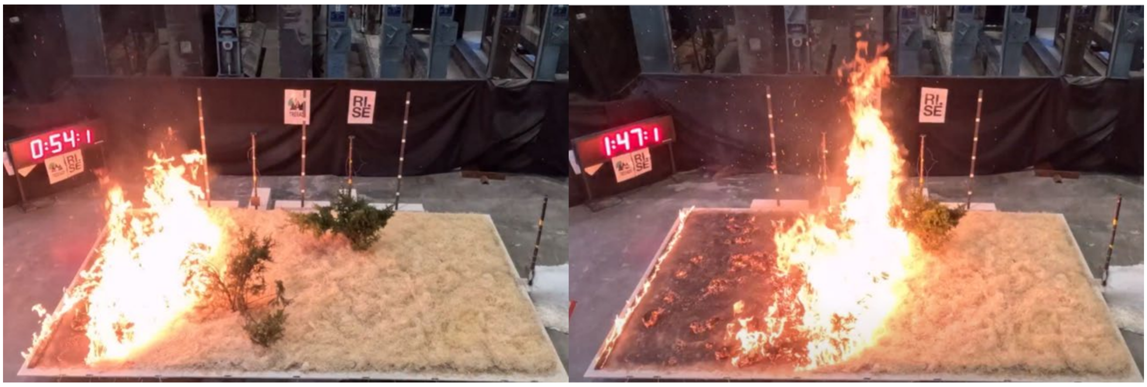


Figure 2-9: Laboratory experiments demonstrating the ladder effect of juniper bushes. Low vegetation burns in the left picture, and in the right picture the junipers ignite and give a significantly larger fire. Photo: RISE Fire Research/ TREEADS.

Figure 2-10: Slopes increase the fire hazard, giving faster spread of the fire and longer flames. In the left column, the fuel bed is horizontal. In the right column, the fuel bed is tilted 20 degrees, giving faster fire spread and increased flame lengths. Figure by RISE Fire Research/TREEADS, taken from [13] with permission from the authors.

2.4 Fire-Treated Wood: Resistance to Wildfire Exposure

One of the technologies developed in TREEADS to improve preparedness for wildfires is fire-treated wooden facades. Norwegian building tradition favours wooden façade materials, and when discussing non-combustible facades with stakeholders in workshops, it was clear that this measure would not be popular in Norway.

In an experimental series, we studied the reaction to fire properties of fire-treated wood used for façade claddings. In small-scale (using a cone calorimeter ISO 5660 [26]), we studied the impact of fire retardant level, type of surface treatment, and wood density, which were all found to be linked with the performance of the product. Medium-scale experiments (using SBI EN 13823 [28]) further highlighted that the level and type of fire retardant, as well as the cavity between the façade material and substrate, were crucial for fire performance. The study also showed that having a section of non-combustible material closest to the ground, before the wood façade material starts also gave a positive effect in terms of protecting the structure from igniting.

In a larger scale, we exposed a 1.5 x 1.5 meter wooden façade to an imitated wildfire spreading up a hill towards the façade (Figure 2-8 and Figure 2-9). For experiments with untreated wood facades and untreated battens in the cavity, the fire spread to the top of the slope, and then spread into the cavity and had to be manually extinguished (Figure 2-8). For experiments with fire-treated wood facades and untreated battens, the fire partially spread to the cavity and then self-extinguished. For experiments with fire-treated wood facades and fire-treated battens in the cavity, the fire spread to the top of the slope but did not spread into the cavity (Figure 2-9). This demonstrated that fire-treatment of wooden façade materials may give improved protection against Norwegian WUI fires, and this is therefore included in supplementary recommendation 2.

Details on the small-scale experiments are presented in report D4.6, and details of the demonstrations on medium and larger scales are presented in report D8.3, which will be available here once published: https://treeads-project.eu/resources/deliverables/.

Figure 2-11: Fire spread in the experimental set-up with an inclined fuel bed and untreated wooden materials. Note that the cavity behind the cladding caught fire and had to be extinguished. (Photo: RISE Fire Research/TREEADS).

Figure 2-12: Fire spread in the experimental set-up with an inclined fuel bed and treated wooden materials. Note that the cavity behind the cladding did not catch fire. (Photo: RISE Fire Research/TREEADS).

2.5 Study of WUI guidelines from other countries

A review of guidelines from other countries was conducted to explore recommendations for managing WUIs from various countries, including the United States, Canada, and Sweden. The selection of these guidelines was chosen for their country's wildland similarity to Norway and that they were in English or a Scandinavian language.

The fire protection resources in the review are as follows:

- FireWise (USA) [29]

FireWise is a trademark operated by the NFPA in the USA. This focuses on the protection of structures in the WUI from a community and individual perspective. To protect individual structures from wildfire the exteriors, such as roofs and exterior cladding, should be made from non-flammable material. Residences should also ensure signage and access to aid firefighting services. In addition, residents should clear areas around houses from flammable materials.

- FireSmart (Canada) [30]

FireSmart is a Canadian WUI guideline similar to FireWise. It is implemented by states and territories in different forms, but the base recommendations are the same regardless of geographical variations. The main difference between states/territories, and between this guideline and USA's FireWise mainly concern the plants that are regarded as flammable/non-flammable. FireSmart is also available as an app to guide users through a series of questions to help identify specific actions that may reduce the impact of wildfires on homes and properties.

- The NRC WUI guidelines (Canada) [31]

Canada has a national guideline concerning the risk, vulnerability, assessment, and mitigation of WUI fires that is developed by the National Research Council of Canada (NRC). The objective of this document is to limit the injuries to persons and the damage to structures caused directly or indirectly by WUI fires. This is a comprehensive guide detailing risk, vulnerability, land management, access, egress, water and power supply, community planning, construction materials, emergency planning, and outreach.

- MSB's information website (Sweden) [32]

The webpage of the Swedish Civil Contingencies Agency (MSB) contains information for the public on mitigation and response to various disasters. MSB provides a short guide for private citizens to protect their houses from wildfires. They have a dedicated page from 2019 for the prevention of forest and vegetation. Here, measures for fire prevention for forest workers and owners are given, and information on emergency preparedness is presented, and steps to take to protect a home from a wildfire are given. Since Swedish nature and society are similar to Norway, the recommendations by MSB, combined with MSB's input in workshops (section 2.6) have been important in the development of the Norwegian WUI guideline.

2.6 Stakeholder engagement to refine recommendations

The WUI guidelines from other countries were gathered in an extensive list of recommendations and topics, which were refined into a non-overlapping list through comparison and summarization. Findings from case studies of past fires, literature, field work and laboratory work presented above were utilized in making a refined list of recommendations. The refined recommendations were presented at a stakeholder workshop (Figure 2-11), where participants rated each recommendation's perceived importance and feasibility in a Norwegian context. The feedback was analysed, resulting in a consolidated list of 14 recommendations categorized as recommended, not recommended, or uncertain.

Figure 2-13: Workshop with stakeholders to collect input and refine recommendations, to ensure relevance to local conditions. Photo: RISE Fire Research/TREEADS.

The list of recommendations was further evaluated through a questionnaire distributed to individuals with expertise or vested interest in fire safety. Responses from the questionnaire informed revisions by the project group, including rewording and translation into Norwegian. A second workshop was held to facilitate discussions and gather final comments. The recommendations were then finally reviewed and finalized in collaboration with the Norwegian Directorate for Civil Protection (DSB). Chapter 3 presents the six main recommendations, and the chapter 4 presents the five supplementary recommendations.

3 Main recommendations | Hovedanbefalinger

This chapter presents the six main recommendations, given in a non-prioritised order, in English and Norwegian with small illustrations. The full illustration can be found in the summary.

3.1 Recommendation 1 | Anbefaling 1

Remove debris, such as pine needles, leaves, and mulch from the structure and immediate vicinity (including decks, gutters, and roofs). Slopes increase the fire hazard.

Fjern rusk, som barnåler, blader og bark, fra bygningen og området rundt (inkludert terrasser, takrenner og tak). Skråninger øker brannfaren.

The recommendation to clear the immediate vicinity of the structure is found in several other guidelines and is often one of the first to be mentioned. Doing this will increase the chances of a structure surviving wildfires spreading by direct flame contact and by spotting. Fires spreading uphill on a slope spread faster than downhill or along a flat surface (Figure 3-1). This is emphasized in the NRC guideline and is also very relevant in Norway, where many structures are situated on slopes. This was also demonstrated in our laboratory experiments (Figure 2-10). For structures situated on slopes, it is worth considering having a larger defensible space on the sloped side of the structure.

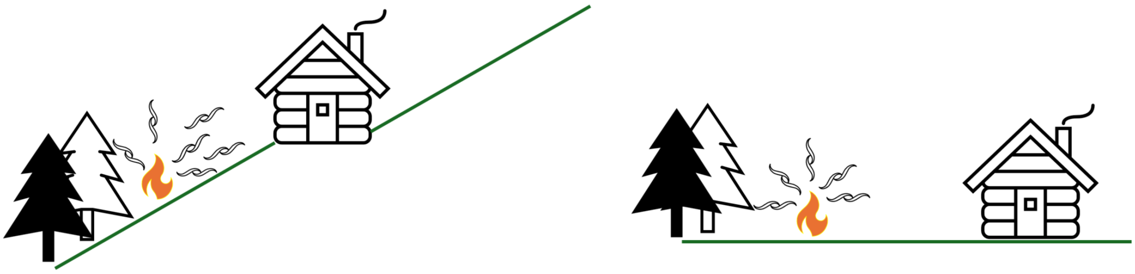


Figure 3-1: Left: A fire on a slope will move up the slope. The ground above it will be more exposed to the radiation from the fire, causing it to preheat more and burn faster. Right: A fire on flat ground will heat the area in front of it slowly and progress slower than it would if there was a slope. Illustration: RISE Fire Research/TREEADS.

3.2 Recommendation 2 | Anbefaling 2

Keep the lawn or vegetation around the structure short and alive.

Hold plenen eller vegetasjonen rundt bygningen lav og levende.

Variations of this recommendation are present in several other guidelines. It takes different forms such as "protection of the immediate zone" but is a generally very accepted measure to prevent wildfires from igniting structures. This one is also particularly important for Norway where many structures such as cabins are located in forested areas with a lot of vegetation very close to the structures. It is common that the vegetation near a cabin in Norway is longer than the vegetation near permanent homes, both due to aesthetic preferences but also that cabins are often left unvisited for weeks or months. Around cabins it is also common to have heather vegetation, and for those cases, a compact ground is beneficial to prevent fire spread to the structure. For heather, human activity and walking/stomping on the ground will therefore be beneficial (Figure 3-2, left). We have not given specific moisture- or length-recommendations for the vegetation, to leave some freedom for interpretation. The vegetation and moisture content of vegetation near a cabin in the mountains can be very different from suburban houses bordering the forest.

Another related aspect is the Norwegian tradition of using vegetated roofs, known as "torvtak" (Figure 3-2, right). These roofs are not at risk from ground-level fires but can ignite from flying burning/glowing embers. However, the recommendation remains relevant. Keeping the vegetation short and alive helps reduce the ignition hazard. Establishing a "fire safe zone" around the structure (see Recommendation 3) can further minimize the risk.

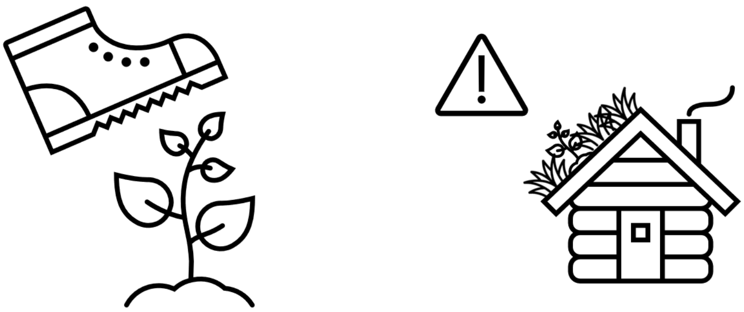
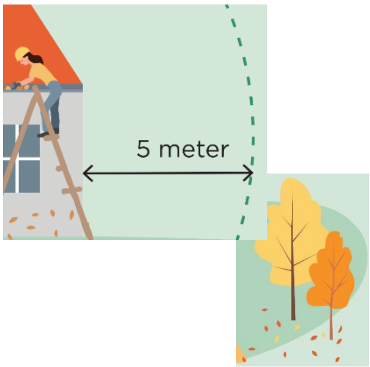


Figure 3-2: Left: Stomping on the heather on the ground around a cabin makes the ground more compact, which is beneficial to prevent fire spread to the structure. Right: Many structures in Norway has vegetation on the roof, and it is important to keep this short and alive to minimize the ignition hazard.

3.3 Recommendation 3 | Anbefaling 3

Have a "fire safe zone" of about 5 metres around the house to protect from wildfires. Plant deciduous trees instead of conifers, avoid junipers and large ornamental plants such as thuja and cypress near the house.



Ha en "brannsikker sone" på ca. 5 meter rundt huset for å beskytte mot skogbrann. Ha løvtrær i stedet for bartrær, unngå einer og større prydbusker som tuja og sypress nær huset.

This recommendation is included for the same reasons as recommendation 2 but focuses more on not having the type of plants that will burn longer and more intensely very close to the house. It was observed during field work, see chapter 2.2, that juniper burns intensely once it is ignited. This was also shown during the laboratory experiments, where juniper increased the intensity of otherwise smaller fires. There have been discussions throughout the development of this guideline about the use of the phrase "brannsikker sone" and the specification of five metres. The term "defensible space" is often used in English, and there is no corresponding established term in Norwegian. As for the five metres, this is an adaptation of several guidelines, and the exact distance is not crucial. The five metres was chosen to give a general reference to avoid misunderstandings, such as assuming a distance that is either too small or excessively large.

3.4 Recommendation 4 | Anbefaling 4

Safe storage: Store materials and items (such as lawnmowers, firewood, furniture, toys, etc.) away from structures.

Sikker lagring: Oppbevar materialer og gjenstander (slik som gressklipper, vedstabel, møbler, leker osv.) i god avstand fra bygninger.

This recommendation helps reduce the chance of a structure igniting from both direct flame contact and spotting. Similar measures appear in several other guidelines and have been adapted to reflect common items found in Norway. Storing flammable materials too close to a structure increases the likelihood of ignition, as they can generate enough heat and flames to set the structure on fire. Throughout the development of this guideline, there have been requests for a more precise definition of how far such materials should be kept from structures. However, the appropriate distance depends on various factors, including how much the materials might contribute to a fire if ignited. Exact distances are not provided here to avoid creating a false sense of security. Instead, the goal is to raise awareness of wildfire risks and encourage proactive measures to minimize the chances of structural loss.

3.5 Recommendation 5 | Anbefaling 5

Clear the dead grass around the house in autumn before the snow arrives. This significantly reduces the severity of a spring fire.

Fjern dødt gress rundt huset om høsten før snøen kommer. Dette reduserer alvorlighetsgraden av en vårbrann betydelig.

This recommendation is unique to the Norwegian guidelines and tailored specifically to Nordic conditions. Norway experience significantly more wildfires affecting structures in spring than in summer (see section 2.1), as is the case in Sweden. Several of these fires occur during prescribed burns intended to clear dead grass and winter debris.

This recommendation may conflict with guidance from some environmental organizations, which advocate leaving dead grass and leaves in place until winter to support biodiversity. For those who wish to follow this advice, we suggest moving the debris far from the house to reduce the structure's vulnerability to wildfires.

3.6 Recommendation/anbefaling 6

Reduce the amount and size of places and cavities where embers can lodge and smoulder. Focus on roofs, eaves/rafters and ventilation openings. Seal or ember proof any cavities and ventilation openings, for example, by using mesh/spark arrestors.

Reduser antall og størrelse på steder og hulrom hvor glør kan sette seg fast og ulme. Fokuser på tak, gesims/raft og ventilasjonsåpninger. Tett eller sikre hulrom og ventilasjonsåpninger, for eksempel ved bruk av gnistsikkert nett.

This measure is mainly focused on preventing ignition from spotting. Spotting is not the most common cause of structure loss in Norway but is still a threat especially if there are places where embers can lodge and smoulder. In the review of case studies from Norway and other countries (section 2.1), we have seen several examples where this measure has contributed to protecting ignition.

4 Supplementary recommendations | Tilleggsanbefalinger

This chapter presents the five supplementary recommendations, given in a non-prioritised order, in English and Norwegian. These recommendations are more expensive and labour intensive than the six main recommendations. They are provided as recommendations to consider, for example, when constructing or renovating a house.

4.1 Supplementary recommendation 1 | Tilleggsanbefaling 1

Fire-safe outdoor spaces: If you have a deck, patio or veranda, use fire resistant materials that are non-combustible or are fire-resilient.

Brannsikre uteplasser: Hvis du har en terrasse, platting, eller veranda, bruk byggematerialer som er ubrennbare eller lite brennbare.

This recommendation will impede ignition from flame contact and spotting. Many Norwegian homes feature wooden porches that are more likely to catch fire than the structure itself. As a result, a structure may withstand direct ignition from a wildfire but still be vulnerable to WUI fires if the porch catches fire first. Given Norway's strong tradition of using wood in construction, we have chosen to not only recommend non-combustible materials (as is the case in some guidelines internationally), but also encourage considering the fire resistance of combustible materials when making material choices.

4.2 Supplementary recommendation 2 | Tilleggsanbefaling 2

Fire resistant siding/cladding: Use fire-resistant siding materials like cement fibreboard, metal or fire-treated wooden materials for better fire protection. It is especially important that the area closest to the ground is well protected.

Brannsikker kledning: Bruk kledningsmaterialer som sementfiberplater, metall eller brannbehandlet treverk for bedre beskyttelse mot brann. Det er særlig viktig at området nærmest bakken er godt beskyttet.

This recommendation is especially important for protecting structures from flame contact. Regarding the use of fire-treated wooden materials, as can be seen in section 2.4, fire-treated wooden materials in the experiments experienced less fire damages and the cavity behind did not catch fire as opposed to the non-treated wood. Since direct flame contact seems to be the most common spread mode in Norway, we have emphasized that the area closest to the ground is particularly important to protect. In the case studies (section 2.1) at least one case in Norway has been identified where a house was saved by the presence of a stone foundation that hindered flame contact to ignite the house. Also in the lab studies (section 2.4) we have found that having non-combustible materials close to the ground can make a positive difference, also for the case of a wooden structures.

4.3 Supplementary recommendation 3 | Tilleggsanbefaling 3

Fire resistant roofing: Use fire-resistant roofing materials, such as metal and tiles to protect against fire.

Brannsikkert tak: Bruk brannsikker taktekking som metall eller takstein for å beskytte mot brann.

This recommendation is focused on preventing ignition from spotting and embers lodging and igniting a structure. For structures in close contact with trees, having a fire-resistant roof and cladding can reduce the likelihood of ignition from direct flame contact, including crown fires, but a preferred measure would be to remove the tall vegetation near the structures, as given in recommendations 2 and 3.

4.4 Supplementary recommendation 4 | Tilleggsanbefaling 4

Fire resistant windows and doors: In the event of a large wildfire, fire resistant windows and doors can help prevent the fire from spreading into the house.

Brannsikre vinduer og dører: Ved store skogbranner vil brannsikre vinduer og dører kunne hindre at brannen sprer seg inn i huset.

This recommendation is to prevent glass in windows or doors shattering due to heat, which could create an entry point for embers to ignite the house from within. This is a common precaution in areas where fires are more intense than in the Nordic countries but is less relevant to Norway where fires are generally smaller and less intense.

4.5 Supplementary recommendation 5 | Tilleggsanbefaling 5

Avoid combustible fences or hedges being in contact with the structure to prevent fire spread pathways to the home.

Unngå at brennbare gjerder eller hekker er i kontakt med bygningen, for å unngå brannspredningsveier til hjemmet.

This recommendation is to prevent a fire from spreading along a fence or hedge to the structure. The practice of fences that run right next to a structure is not very common in the rural areas of Norway, which is where many WUI areas are found. It is still a recommendation that should be considered while during construction or renovations.

5 Recommendations that are not included

The recommendations in this chapter have either been considered too labour intensive or expensive to implement, alternatively that they have not been found to be effective against hindering structure loss in WUI areas. The recommendations are presented in a non-prioritised order.

5.1 Recommendation not included 1

Roof or façade sprinklers: Consider installing roof or façade sprinklers connected to a water source for fire protection (special cases).

This was found to be a disproportionately expensive measure to implement for private homes in WUI areas in Norway, but may be considered for structures of cultural and historical value, or those with other essential functions for society.

5.2 Recommendation not included 2

Avoid intricate carvings or decorations on facades or roofs that are easily ignited.

In recommendation 6, it was considered to include to reduce the hazard of embers lodging and smouldering, as well as to minimize the likelihood of direct flame contact igniting a structure. However, ember-driven fire spread is not the most common ignition source in Norway's WUI areas, and decorative elements of this kind are relatively uncommon in Norway today. No clear evidence indicated that such a measure would significantly enhance a structure's wildfire resilience in Norway. Given the limited data and the fact that wildfires do not currently pose a substantial enough threat to justify restricting what is ultimately a matter of personal preference, the recommendation was not included.

5.3 Recommendation not included 3

Paint your house regularly to minimize the chances of fire ignition and spread.

This recommendation was discussed multiple times but no scientific data was found that could strengthen the claim that this would enhance a structure's safety during a wildfire. The reason this point appears in some other WUI guidelines worldwide may be that regular painting is often linked to overall property maintenance and upkeep, which *is* included and emphasized in several other recommendations within this guideline.

6 Conclusions

This guideline provides essential recommendations to enhance wildfire resilience in Norway's WUI areas, ensuring that built environments are better protected from potential fire hazards. Developed through research, stakeholder input, and adaptation to Norwegian conditions, it serves as a crucial resource for residents, first responders, and policymakers.

As the fire risks and building practices evolve, it is important to reassess and update these recommendations. This guideline reflects the situation per 2025 and should be regularly updated to remain relevant and effective in mitigating wildfire risks.

A natural next step in implementing this guideline for public use is to translate it to multiple languages and to integrate the recommendations into an app or other gamified formats to boost engagement.

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