FirEURisk - DEVELOPING A HOLISTIC, RISK-WISE STRATEGY FOR EUROPEAN WILDFIRE MANAGEMENT

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Authors:	Vassiliki Varela, George Eftychidis, Bachisio Arca, Giovanni Laneve, Miguel Almeida, Michele Salis
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Executive Summary

The deliverable D2.1 of the FirEURisk project presents a comprehensive set of guidelines developed through a rigorous methodology to reduce wildland fire ignitions across various European regions. The methodology encompasses a thorough literature review, extensive data analysis within the FirEURisk project's Task 2.1, stakeholder consultations, focus group discussions, and expert judgement to ensure a multifaceted approach to wildfire prevention.

The deliverable's "Results" section provides an insightful analysis of the current situation and trends of wildland fire ignitions, identifying key drivers such as climate change, land use, management, and socioeconomic factors. It also addresses the challenges, including data availability, quality, and the intricacies of prevention and mitigation efforts. Additionally, challenges associated with wildland fire ignitions are identified, including data availability, prevention, mitigation, and the complexities of adapting to environmental changes. Best practices and lessons learned from existing policies in the EU are also analyzed, highlighting the need for nuanced approaches tailored to different environmental and infrastructural contexts.

The heart of the deliverable lies in the Guidelines section, which offers specific recommendations categorized into legal/policy, technical, and educational/social aspects. These guidelines address a wide-range of topics, including detailed Acceptable Safety Distances (ASDs) for critical infrastructure such as power grids, road networks, and railways, adjusted based on climate conditions and vegetation types. They also place a strong emphasis on collaboration with local authorities, maintenance of critical infrastructure, public awareness, and education initiatives.

Overall, the document provides a succinct summary of key challenges and opportunities for reducing wildland fire ignitions and underscores the importance of proactive measures in mitigating risks. It suggests integrating advanced technologies like AI and remote sensing for effective wildfire risk management and emphasizes the need for collaboration across sectors and stakeholders to implement the proposed guidelines effectively.

The deliverable is tailored for policymakers, fire management authorities, researchers, infrastructure managers, and stakeholders engaged in the realm of wildland fire prevention and management. Informed by the FirEURisk project's findings, it provides a strategic framework for reducing wildfire risk and serves as a valuable tool for , guiding policy development, planning, and implementation efforts aimed at mitigating wildland fire risks with a particular focus on strategies to reduce fire ignitions.

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Table of Contents

1 Introduction 11

1.1 Purpose of the document 11

1.2 Structure of the Document 12

2 Methodology 14

2.1 Literature review 14

2.2 Data Analysis 20

2.2.1 Development of FirEUrisk Framework for reducing operation-based ignitions 20

Analyses for Level A 21

Analyses for Level B 23

Homogeneous Territorial Class (HTC) calculation 24

2.3 Stakeholder Consultation 24

2.4 Expert Judgment 26

3 Results 28

3.1 Current situation and trends of wildland fire ignitions 28

3.1.1 Fire ignitions and trends in EU countries 28

Brief analysis on fire ignitions in EU countries 31

Recommendations 32

3.1.2 National Legislation and Regulations in EU 33

Comprehensive Analysis and Policy Recommendations for Fire Management and Critical Infrastructure 44

Gap Analysis and Future Directions 46

3.2 FirEUrisk Framework for Reducing operations-based fire ignitions 46

3.3 Main drivers and challenges of wildland fire ignitions 49

3.3.1 Main Drivers of Wildland Fire Ignitions 49

Climate Change 49

Land Use and Management 49

Socioeconomic Factors 50

3.3.2 Challenges Associated with Wildland Fire Ignitions 51

Data Availability and Quality 51

Prevention and Mitigation Aspects 51

Environmental Considerations 51

Fuel treatment near critical infrastructure 51

3.4 Policies, best practices and lessons learned 52

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3.4.1 Lessons Learned 53
3.4.2 Policies in the EU 53
3.4.3 Best Practices 54

4 Guidelines 54

4.1 State of the art 54

4.1.1 Existing guidelines 54
4.1.2 Guidelines for Acceptable Safety Distances (ASDs) Near Critical Infrastructure 56

4.2 Guidelines related to legal aspects and Policy 57

4.2.1 Power network 57

Utility Liability and Accountability 57
Regulatory Oversight 57
Utilities' Emergency Response Plans 57
Encourage Coordination with Local Authorities 57
Government Mitigation Funding and Incentives 57
Legal Frameworks for Public Awareness and Education 57
Legislation on Equipment Standards 58
Climate Adaptation Policies for power network planning 58

4.2.2 Road network 58

Maintain vehicle properly 58
Avoid parking on dry vegetation: 58
Be cautious with towing equipment: 59
Avoid off-road driving 60
Report any signs of fire 61
Fire restrictions and bans 62
Roadside parking regulations 62
Off-road driving restrictions 63
Proper disposal of smoking materials 64
Reporting requirements 64

4.2.3 Rail network 65

4.3 Technical Guidelines 66

4.3.1 Critical infrastructure 66

Thorough Maintenance 66
Regular Inspections 66
Installation of Protective Measures 66
Base ASD Guidelines 66
Base ASD Guidelines for Power Grids 66

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Base ASD Guidelines for Road Networks 67
Base ASD Guidelines for Railways 67
Base ASD Guidelines for Other Infrastructure 68
Climate-Adjusted ASD Guidelines for Power Grids 68
Climate-Adjusted ASD Guidelines for Road Networks 69
Climate-Adjusted ASD Guidelines for Railways 69
Relative ASD Multipliers Based on Vegetation Type for Power Grids 70
Relative ASD Multipliers Based on Vegetation Type for Road Networks 70
Relative ASD Multipliers Based on Vegetation Type for Railways 71
4.4 Guidelines related to educational and social aspects 72
4.4.1 Educational Initiatives 72
Awareness Campaigns 72
School Programs 72
Community Workshops 72
4.4.2 Social Engagement 72
Community Involvement: 72
Volunteer Groups for fire prevention 72
Partnerships for the development of fire prevention plans 72
4.4.3 Behavioral Changes 72
Promoting Safe Practices 72
Reporting Suspicious Activities 72
Adopting Firewise Landscaping 73
4.4.4 Communication Strategies 73
Social Media Campaigns 73
Public Service Announcements (PSAs) 73
Signage 73
5 Conclusions 73
6 References 75
7 Annexes 75
7.1 Annex A: FirEUrisk Consortium Questionnaire
7.2 Annex B. Completed Questionnaires

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List of Figures

Figure 1: Zone of analyses around networks & point assets/ Acceptable Safety Distance (ASD) for each type of network & asset 43
Figure 2: Estimation of Rate of Spread under a selected weather scenario for the PS 44
Figure 3: Ignitions Density map (ID) based on operations-based past-fire ignitions 44
Figure 4: Fuel Treatment Priority map 45

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List of Tables

Table 1: List of Acronyms 10
Table 2: List of Contributors 11
Table 3: Literature – Collection of articles & reports 17
Table 4: HTC_ROS classes (classification of HTC_ROS values) 22
Table 5: Danger Values of each parameter for the calculation of FRM danger values (according to PREFER project classification) 22
Table 6: FRM priority classes (classification of FRM danger values) 23
Table 7: Ranges for the subdivision into Homogeneous Territorial Classes (HTCs) for Prescribed Burning (according to PREFER project classification) 24
Table 8: Data on wildfires and critical infrastructure 28
Table 9: Existing laws and regulations on wildfires and critical infrastructure 34
Table 10: Gap Analysis on wildfires and critical infrastructure 42

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List of Acronyms

Table 1: List of Acronyms

List of Acronyms	
AOI	Area of Interest
ASD	Acceptable Safety Distance
DA	Demonstration Area
EFFIS	European Forest Fire Information System
EFI	European Forest Institute
EFIMED	EFI's Mediterranean Facility
EU	European Union
FLIN	Fireline Intensity
FTPM	Fuel Treatment Priority Map
GIS	Geographical Information System
HTC	Homogeneous Territorial Class
IFM	Integrated Fire Management
IP	Ignition Potential
FRM	Fuel Reduction Map
PID	Past Ignitions Density
PS	Pilot Site
ROS	Rate of Spread
ROScl	Rate of Spread class
RWMP	Regional Wildfire Mitigation Programs
TFT	Typical Fuel Treatment
UAV	Unmanned Aerial Vehicles
WUI	Wildland-Urban Interface

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Table 2: List of Contributors

FirEURisk Questionnaire Contributors		
Questionnaire Design	AUTH	George Eftychidis
Data collection	AUTH	Vassiliki Varela
Croatia	FESB	Darko Stipanicev
Cyprus	EUC	Klelia Petrou, Iasonas Senekkis
Finland	ARBO	Tuomo Vuorenpää, Ana Basic
France	Safe Cluster	Sebastien Lahaye
Greece	AUTH	George Eftychidis
Italy	SIA	Giovanni Laneve
Netherland	VUA	Neidermeier Alexandra
Portugal	ADAI	Miguel Almeida
Spain	Lleida	Maria Cristina Vega Garcia
Scotland	HUT	Maria Nijnik

1 Introduction

1.1 Purpose of the document

Reducing forest fire ignitions is a key strategy for preventing and mitigating the impacts of forest fires.

Forest fire ignitions can be classified into two main categories: natural and human-caused. Natural ignitions are those that result from lightning strikes, volcanic eruptions, or spontaneous combustion. Human-caused ignitions are those that result from deliberate or accidental actions, such as arson, campfires, agricultural burning, logging, power lines, or fireworks.
Reducing forest fire ignitions requires a comprehensive and integrated approach that involves various stakeholders, such as governments, communities, landowners, industries, and researchers.

Operational based forest fire ignitions relate to the causes, effects, and solutions for forest fire ignitions that result from human activities, such as logging, power lines, or fireworks. Operational based forest fire ignitions are a common and increasing problem in many regions of the world, especially in areas where human development and natural vegetation coexist.

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According to the Global Fire Emissions Database [1], human-caused ignitions account for about 84% of the global fire activity. These ignitions can have severe consequences for ecosystems, biodiversity, human health, infrastructure, and livelihoods. They can also contribute to climate change by releasing greenhouse gases and aerosols into the atmosphere. Therefore, reducing operational based forest fire ignitions is a key strategy for preventing and mitigating the impacts of forest fires.

There are different methods and techniques for reducing operational based forest fire ignitions, depending on the type, location, and function of the operations, as well as the nature and magnitude of the hazard.

The purpose of the deliverable is to provide actionable recommendations and strategies aimed at minimizing the occurrence of forest fires caused by human activities. These guidelines can serve several important objectives:

Risk Reduction: By providing clear guidelines, the aim is to lower the risk of forest fires ignited by human actions.

Preservation of Ecosystems: Forest fires can have devastating effects on ecosystems, wildlife habitats, and biodiversity. Guidelines aimed at reducing fire ignitions help preserve these sensitive environments.

Protection of Human Lives and Property: Forest fires pose a significant threat to human lives, property, and infrastructure in surrounding areas. Implementing effective guidelines can help mitigate these risks.

Cost Reduction: Fighting forest fires is expensive, both in terms of resources and infrastructure damage. By reducing the number of fire ignitions, the costs associated with fire suppression and recovery can be minimized.

Community Awareness and Education: Providing guidelines raises awareness among communities about the causes of forest fires and empowers them to take preventive actions. Education plays a crucial role in fostering responsible behavior and reducing human-induced fire incidents.

Collaboration and Cooperation: The development of guidelines often involves collaboration between various stakeholders, including government agencies, environmental organizations, fire departments, and the public. This collaborative effort fosters cooperation in addressing the shared challenge of forest fire prevention.

Overall, the current deliverable outlining guidelines to reduce forest fire ignitions aims to promote proactive measures that safeguard both natural resources and human interests, ultimately contributing to the sustainable management of forest ecosystems.

1.2 Structure of the Document

The structure of D2.1 provides a detailed overview of the document, starting with the introduction and methodology, followed by results, guidelines, conclusions, references, and an annex for additional information. Each section is further subdivided to sub-sections for the purpose of clarity and organization.

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The deliverable's structure, centered around the theme of reducing wildland fire ignitions, is organized to provide a comprehensive guide for stakeholders. Here's a detailed description of its composition:

The Methodology section (Section 2) is the backbone of the deliverable, detailing the systematic approach taken to develop the guidelines. The subsections of this section include:

- Literature Review: This subsection outlines the literature review process, including defining the scope, research questions, keywords, inclusion and exclusion criteria, and information sources. It involves searching for relevant literature, screening and selecting based on set criteria, and analyzing and synthesizing the data to draw meaningful conclusions.

- Data Analysis: Here, the deliverable delves into the data analysis conducted within the FirEUrisk project Task 2.1, crucial for informing the guidelines.

- Focus Group Work: Describes the interactions with focus groups, providing a qualitative dimension to the research.

- Expert Judgment: The FirEUrisk Consortium's questionnaire on 'National Legislation for Forest Fire Prevention Associated with Critical Infrastructure' aims to gather comprehensive data and informed perspectives from both regional and national experts, thereby enriching the guidelines with substantial depth and specialized knowledge.

The Results section (Section 3) presents the findings from the methodology, offering a clear picture of the current state of wildland fire ignitions. It includes an analysis of the current situation and trends in various regions, informed by the FirEUrisk project's results, especially activities of Task 2.1 of the project (A2.1.1 and A2.1.2). A brief analysis of the main drivers, such as climate change, land use, management, socioeconomic factors, and challenges like data availability and quality, is provided and finally, best practices and lessons learned from existing fire prevention policies in the EU are shared, offering valuable insights.
The Guidelines section (Section 4) is core content of the deliverable that offers specific and practical recommendations for reducing wildland fire ignitions. The guidelines are organized into categories or themes, such as legal, technical, and educational and social aspects, for clarity and ease of implementation.
The conclusive section (Section 5) summarizes the main points and messages of the deliverable. It discusses the key challenges and opportunities for reducing wildland fire ignitions. The benefits and limitations of the guidelines are weighed, and the potential implications and applications for different stakeholders and sectors are explored.
A comprehensive list of all the sources are referenced throughout the deliverable (Section 6), allowing for further exploration. Finally, the annex provides supplementary material that supports the main content, offering additional depth and context.

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2 Methodology

The methodology for the development of the FirEURisk Guidelines for reducing fire ignitions included the following steps:

- Reviewing the existing literature and best practices on WUI fire causes, effects, and solutions, as well as the gaps and challenges in the current knowledge and practice.
- Analyzing the methods and products that have been developed in the frame of the FirEURisk project and more particularly in Task 2.1, which were implemented in the project's Pilot Sites.
- Collecting and analyzing the FirEURisk Consortium Questionnaire "National Legislation on Forest Fire Prevention Linked to Critical Infrastructure".
- Discussing and synthesizing the main findings and implications of the literature review and the case studies, and providing recommendations for future research and action.
- Summarizing the main points and conclusions of the guide in a concise and user-friendly format.

2.1 Literature review

The literature review on reducing forest fire ignitions serves as a critical component of understanding the existing knowledge, identifying gaps, and establishing a foundation for future research and policy development.

Key considerations for defining the scope of the literature review on fire ignitions are the following:

- Global and Regional Perspectives: Explore literature that provides a global perspective on forest fire ignitions while also delving into region-specific studies. Different regions may face unique challenges and require tailored prevention strategies.
- Socioeconomic Factors: Investigate the role of socioeconomic factors in forest fire ignitions. This involves examining the influence of population dynamics, economic activities, land use changes, and cultural practices.
- Effectiveness of Prevention Measures: Evaluate existing literature on the effectiveness of various prevention measures, including regulatory approaches, community engagement, technological solutions, and land management practices.
- Climate Change Impacts: Assess how climate change influences forest fire regimes and ignitions. Investigate studies that explore the link between changing climate patterns and increased fire risks.
- Interdisciplinary Approaches: Consider literature from interdisciplinary perspectives, incorporating studies from fields such as ecology, sociology, and policy analysis. This can provide a comprehensive understanding of the issue.
- Technological Innovations: Review literature on the use of technology in preventing forest fire ignitions, such as early warning systems, remote sensing, and innovative firefighting tools.
- Community Involvement: Investigate studies that highlight the importance of community involvement in fire prevention. This includes community-based initiatives, education campaigns, and participatory approaches.

The Wildland-Urban Interface (WUI) plays a significant role in fire ignitions due to several factors:

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1. Increased Human Activity: The WUI is characterized by increased human presence and activity, which can lead to more accidental ignitions from sources like campfires, smoking, and machinery [2]

2. Higher Density of Structures: The presence of more structures in the WUI can increase the likelihood of fires starting from structural issues, such as electrical faults or improper disposal of hot materials [3]

3. Vegetation Management: In the WUI, the proximity of wildland vegetation to urban areas can contribute to fire ignitions if not properly managed. Overgrown or dead vegetation can serve as fuel for fires [4]

4. Climate Change: Climate change has led to more extreme weather conditions, such as droughts and heatwaves, which can dry out vegetation and make the WUI more susceptible to ignitions [3]

5. Intermixing of Fuels: The WUI often has a mix of natural and human-made fuels, which can create complex fire behavior and increase the risk of ignitions spreading rapidly [5] Effective management and community involvement are crucial in these areas to reduce the risk of fire ignitions and their potential spread.

The causes of fire ignitions are not exclusive to Europe but are also prevalent worldwide. However, regional differences in climate, land use practices, and socio-economic factors may influence the relative importance of each cause in different parts of the world. Understanding these causes is crucial for developing effective prevention and mitigation strategies to reduce the risk of WUI fires and protect communities and ecosystems.
The article "The Influence of Socioeconomic Factors on Human Wildfire Ignitions in the Pacific Northwest, USA. examines over 104,000 ignitions from 1992 to 2018 in Oregon and Washington, evaluating the influence of both biophysical and socioeconomic factors on human and natural ignitions across distinct fire regimes. [6]
A collection of articles titled "Special Section on Structure Ignition in Wildland-Urban Interface (WUI) Fires [7] from Fire Technology discusses the challenges of WUI fire spread, the science behind firebrand ignition of structures, and the effectiveness of building codes and standards in reducing the risk of structural ignition.
"The wildland–urban interface fire problem – current approaches and research directions" [8] is a paper provides an overview of the current state of research on the WUI fire problem, including the causes of initial structure ignitions and the exposure to heat flux from flames or firebrands generated by a wildfire.
In Europe, particularly in southern regions, the expansion of WUI areas has been linked to the abandonment of dwellings around former grazing lands, migration to cities, and a decrease in traditional forest activities, leading to significant biomass accumulation. This biomass serves as fuel for fires, which are frequently ignited by human activities [9],[10].

The primary causes of Wildland-Urban Interface (WUI) fire ignitions in Europe and worldwide are multifaceted, involving a combination of human activities, environmental conditions, and land-use changes. Based on the literature the following causes can be summarized:

- Human Activities: The majority of WUI fires are related to human activities. This includes accidental ignitions

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from sources like discarded cigarettes, campfires, and agricultural burning, as well as intentional acts such as arson [9], [11].

• Environmental Conditions: Weather patterns, such as prolonged droughts, heatwaves, and strong winds, contribute to the likelihood and spread of WUI fires. Climate change is exacerbating these conditions, increasing the risk and frequency of such fires [9].

• Land-Use Changes: In Europe, particularly in the southern regions, the expansion of WUI areas has been linked to the abandonment of rural dwellings, migration to cities, and a decrease in traditional forest activities. This leads to biomass accumulation, which can fuel fires [7]. In other parts of the world, like the Americas and Australia, urban development into previously undeveloped wilderness areas is a significant factor [9].

• Vegetation Management: The lack of proper vegetation management around housing developments in WUI areas can lead to an accumulation of fuel for wildfires [9], [12].

• Policy and Planning: Inadequate regulations, codes, and urban planning standards for WUI communities can exacerbate the risk of fire ignitions. There is a need for improved policies that consider the unique challenges of WUI areas [7].

These factors highlight the complexity of wildland and WUI fire ignitions and the need for comprehensive strategies that address both human and environmental aspects to reduce the risk of fires. Globally, the issue is compounded by similar factors, such as lack of vegetation management and increasing urban development of wilderness areas, which also contribute to the accumulation of flammable materials
These conditions, combined with the effects of climate change, such as prolonged droughts and heatwaves, increase the risk and frequency of WUI fires [11].
A more detailed information on policies and recommendations for improving WUI fire prevention and management, particularly in Spain is provided in the Fire Technology journal [7].

Community involvement is essential for reducing wildfire ignitions in the Wildland-Urban Interface (WUI) areas in Europe. Key strategies that have been identified include the following:

1. Regional Wildfire Mitigation Programs (RWMP): These programs aim to retrofit the built environment, buffer the landscape, and train communities to become fire-adapted. They include a consistent methodology for mapping hazards and vulnerabilities, assessing risks, prioritizing mitigation activities, and implementing effective solutions [12].

2. Policy Framework and Recommendations: In countries like Spain, there is a focus on creating better fire-resistant and resilient WUI scenarios through solid regulations and legislation. This includes addressing shortcomings in building and urban planning standards and technical codes for WUI communities [10]

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3. National Guides: Some European countries have developed national guides for WUI fires, providing guidance on hazard and exposure assessment, property protection, community resilience, and emergency planning to minimize the impact of WUI fires [13].

4. Research and Fire Engineering: There's a need for scientific research and fire engineering to address specific topics related to wildfires in Europe and globally. These topics include the planning of low-fuel fringes, design of road networks and accessibility, dimension of water supply networks, and the role of construction methods and materials in WUI fires [10].

These strategies highlight the importance of a comprehensive approach that goes beyond fuel reduction, and involves community education, policy reform, and scientific research to build fire-safe communities and enhance resilience against wildfires in Europe.

The collection of articles and reports provided in Table 3 offers a comprehensive examination of the factors influencing forest fire ignition, with a specific focus on Europe. The analysis also includes a comparison with North American regions. These documents encompass scientific studies on human and environmental influences, technical reports summarizing empirical modeling recommendations, and reviews of decision support systems and fuel treatment optimization. They collectively contribute to a deeper understanding of wildfire prevention, the effectiveness of landscape-scale fuel treatments, and the challenges faced in managing wildland fires. The insights gained from these resources are crucial for developing strategies to mitigate wildfire risks, improve sustainable forest management, and enhance the resilience of critical infrastructure against the backdrop of climate change. This body of work highlights the importance of integrating scientific knowledge with practical applications to safeguard both natural environments and human communities from the devastating impacts of wildfires.

Table 3: Literature – Collection of articles & reports

Title	Description
A Review of the Main Driving Factors of Forest Fire Ignition Over Europe.	A scientific article that examines the human and environmental factors that influence forest fire ignition in the Mediterranean region, and compares them to other regions of the world, with a special focus on North America (US and Canada) where a significant number of studies has been carried out on this topic https://link.springer.com/article/10.1007/s00267-012-9961-z
Wildfire Ignitions: A Review of the Science and Recommendations for Empirical Modeling	A technical report summarising the state of knowledge regarding the underlying causes and the role of wildfire prevention efforts on all major categories of wildfires, including findings from research that have sought to model wildfire occurrences over fine and broad spatial and temporal scales. It also describes a conceptual model of wildfire ignitions, which is designed to provide a modeling framework for analysts who seek to better understand wildfire ignition processes or develop statistical models that can predict wildfire occurrences across any spatial or temporal scale https://www.srs.fs.usda.gov/pubs/gtr/gtr_srs171.pdf

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Optimizing Fuel Treatments to Reduce Wildland Fire Risk	A review article that discusses the recent advances and challenges in fuel treatment optimization modelling, which is a method to identify the optimal locations, types, and intensities of fuel treatments that minimize the expected losses from wildfires. It also provides some examples of fuel treatment optimization models and applications in different contexts and scales https://link.springer.com/article/10.1007/s40725-015-0005-9
A Review of Recent Forest and Wildland Fire Management Decision Support Systems	A review article that provides an overview of the current state of the art and future directions of decision support systems for forest and wildland fire management, which are tools that integrate data, models, and user preferences to facilitate decision making under uncertainty. It also identifies some of the key challenges and opportunities for developing and implementing such systems https://link.springer.com/article/10.1007/s40725-015-0011-y
Fire Ecology - A systematic review of empirical evidence for landscape for landscape-level fuel treatment effectiveness	A systematic review that evaluates the empirical evidence for landscape-scale fuel treatments, which are interventions that modify the spatial arrangement and characteristics of fuels across large areas to reduce the risk and severity of wildfires. It also identifies the knowledge gaps and research needs for improving the effectiveness and efficiency of such treatments https://fireecology.springeropen.com/articles/10.1186/s42408-022-00146-3
Wildland Fire Prevention: a Review	A review particularly insightful, as it discusses the effectiveness of prevention efforts, the spatio-temporal likelihood of fire occurrence, and the influence of human behaviour on wildfire prevention https://link.springer.com/article/10.1007/s40725-018-0083-6
A Review of the Main Driving Factors of Forest Fire Ignition Over Europe	A review which analyzes human and environmental factors in forest fire ignitions and compares them across different regions https://link.springer.com/article/10.1007/s00267-012-9961-z
Reducing wildfire risk in Europe through sustainable forest management: a policy brief	A document that describes the challenges and opportunities for reducing wildfire risk in Europe through sustainable forest management, and proposes actions to enhance cooperation and knowledge exchange https://climate-adapt.eea.europa.eu/en/metadata/publications/reducing-wildfire-risk-in-europe-through-sustainable-forest-management-a-policy-brief
Safe and resilient forests: Commission works for wildfire prevention in Europe and globally	A press release that announces the publication of new guidelines by the European Commission to facilitate a better understanding of land-based wildfire prevention and effective responses, and how EU Member States can access EU funding and work together at EU level

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	https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_21_1225/IP_21_1225_EN.pdf
Land-based wildfire prevention	A brochure that provides an overview of the current and future trends of wildfires in Europe and tools for monitoring them at European and national levels, prepared by the European Commission with the assistance of experts in fire management https://op.europa.eu/en/publication-detail/-/publication/4e6cc1f1-8b8a-11eb-b85c-01aa75ed71a1
Assessing the Effects of Forest Fires on Interconnected Critical Infrastructure under Climate Change. Evidence from South France	A case study on the climate resilience of interconnected critical infrastructure to forest fires, that was performed within the framework on H2020 EU-CIRCLE project (GA 653824). It was conducted in South France, one of the most touristic European regions, and also one of the regions with the highest forest fire risk, projected to be amplified under future climate conditions. https://www.mdpi.com/2412-3811/6/2/16 https://doi.org/10.3390/infrastructures6020016
Landscape-scale fuel treatment effectiveness: lessons learned from wildland fire case studies in forests of the western United States and Great Lakes region	A successful case of innovative approaches in fuel treatment is documented in a study from the western United States and Great Lakes region. The study synthesized information from various case studies that examined the effectiveness of landscape-scale fuel treatments during wildfire events. This case study demonstrates the importance of integrating fuels, topography, prevailing winds, fire history, and available infrastructure into landscape-scale treatment designs to improve fuel treatment effectiveness and wildfire management. https://fireecology.springeropen.com/articles/10.1186/s42408-022-00159-y
Key Recommendations on Wildfire prevention in the Mediterranean New governance for a comprehensive approach to mitigating wildfire risks	This report from the European Forest Institute (EFI) encompasses a series of best-practice cases of fire prevention in the Mediterranean region. It highlights the importance of wildfire prevention as a critical component of wildfire management, especially in the context of climate change. The document showcases innovative initiatives that engage local communities in prevention efforts, which are essential for reducing the probability of fire ignition and managing the growth and force of fire events. The case studies presented by EFI's Mediterranean Facility (EFIMED) in collaboration with the Diputació de Barcelona illustrate successful strategies from various Mediterranean locales, emphasizing community involvement as key to effective wildfire prevention Wildfire prevention in the Mediterranean (efi.int)

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2.2 Data Analysis

2.2.1 Development of FirEUrisk Framework for reducing operation-based ignitions

The product of Activity 2.1.2 is a framework for the definition and prioritization of areas for Fuel Reduction, aiming to the reduction of operations-based fire ignitions. The framework was based on the concept and methodology defined in EU-FP7 PREFER project ("Space-based information support for the Prevention and Recovery of Forest Fires Emergency in the Mediterranean Area" - *G.A.*312931), adapted for linear and point critical infrastructure (i.e. power grids, roads, railways) to depict and prioritize the areas that need to be treated.
The methodology was based on the framework developed in the PREFER project for fuel management and adapted to serve the specific needs of the FirEUrisk activity, for the reduction of operational ignitions. To this end:

- additional spatial layers of risk elements were considered for improving the PREFER approach using advanced airborne sensing technology and methods were identified to map linear infrastructure elements (powerlines, railways, road networks etc.):
- specific (spatial) fuel management rules, methods, and relative physical thresholds to develop local fuel management maps using advanced airborne sensing technology (for mapping WHERE actions are necessary for reducing operations-based ignitions) have been defined

The final product "Fuel Management Framework for the Reduction of Operational Ignitions" was adapted for linear and point critical infrastructures (i.e power grids , roads, railways) to depict and prioritize the areas that need to be treated.

The tools that have been used included UAVs data & Satellite imagery, GIS spatial analysis tools and Fire Simulators.

The following input thematic layers were analysed for the creation of the resulting Fuel Reduction map with three (3) priority classes (low, medium, high) of fuel treatment.

- Power grid (lines) (High-Medium-Low voltage)
- Power substations/pylons/transformers (WUI areas) (points) .
- Railway network (lines)
- Road network (lines, (National, Provincial, Municipal)
- Other installations related to road and railway networks (points)
- Topography (i.e. elevation, slope, aspect)
- Fuel Type map based on FirEUrisk fuel types
- Climatic characteristics/ Zone (Dry, Mild, Wet)
- Ignition points of past fires caused by accident due to the existence or usage of the above infrastructure
- Fire Simulation for a selected weather scenario (prevailing or worst case for the PS/AOI)

The data analyses were performed in two levels, A) PS level analysis and B) DA level analysis and included 3 steps:

<u>Step A: Regional/PS Level Analysis</u>

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1. Layer Overlay: This step involves creating a composite map by overlaying two key layers - the infrastructure networks (power grid, roads, railways) and the vegetation layers (fuel maps or satellite imagery).
2. Identification of Risk Areas: The overlaid map is then analysed to identify regions where vegetation encroaches upon a predefined buffer zone around the infrastructure. These areas are marked as lines or polygons, indicating potential risk zones.

Step B: Local/DA Level Analysis

1. Drone Surveillance: In selected areas, drones are deployed to conduct a detailed survey along the network lines.
2. High-Resolution Mapping: The drone flights provide high-resolution data, enabling precise identification of specific locations where vegetation is too close to the operational network, necessitating fuel treatment.

Step C: Prioritization and Treatment Planning

1. Data Elaboration: The high-resolution data from Step B is thoroughly analysed to understand the nuances of the challenge.
2. Intervention Prioritization: Based on factors such as the type and volume of vegetation, topography, accessibility, and proximity to the network, interventions are prioritized.
3. Treatment Definition: Finally, the type of vegetation management or fuel treatment required is defined for each prioritized area. This could involve methods like controlled burns, mechanical clearing, or chemical treatments, tailored to the specific needs of the location.
The levels of analyses are described in detail below.

Analyses for Level A

The steps of analyses for this level are the following:

1) Create “Typical Fuel Treatment” buffer zones (TFT map layer) along the infrastructure elements and overlay on Fuel map

2) Using Topographic parameters (Slope, Aspect, Elevation) and Environmental parameters (Fuel, Climate) estimate Homogeneous Territorial Class (HTC), as it is defined in PREFER methodology (see subsection 2.2.1.3 “Homogeneous Territorial Class (HTC) calculation”)

3) Create “Ignition Potential” buffer zones (IP map layer) around infrastructure elements (points and lines)

4) i. Create Past Ignitions Density [PID] (for the past 20 years) map layer (GIS analysis using 5-10 m cell size and 200 m radius where accurate ignition locations exist OR number of ignitions/administrative unit where no accurate ignition locations exist)

ii. Classify PID map in three classes (low-medium-high)

5) i. Calculate Rate of Spread (ROS) map under a worst-case meteorological scenario using a fire simulator

ii. Calculate mean Rate of Spread for all the cells of each HTC (HTC_ROS map layer)

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iii. Classify HTC_ROS value map layer (HTC_ROScl - five classes according to Table 4)

Table 4: HTC_ROS classes (classification of HTC_ROS values)

HTC_ROS values m/min	HTC_ROS class
0- 10	1 very low
11-30	2 low
31-60	3 medium
61-100	4 high
> 100	5 extreme

6) Create Acceptable Safety Distance (ASD) buffer zones (ASD map layer).

The Acceptable Safety Distance (ASD) around infrastructure elements (points and lines) may vary depending on the type of Infrastructure (e.g. high/medium/low voltage power lines, roads, railways etc.).

7) Combine TFT , HTC_ROScl, IP, PID and ASD map layers for the calculation of the danger values of the Fuel Reduction map based on Table 5. The SUM of the danger values of all the parameters for each cell of the map provides the danger values of the Fuel Reduction Map.

Table 5: Danger Values of each parameter for the calculation of FRM danger values (according to PREFER project classification)

TFTd (m)	HTC_ROScl	IP (m)	PID	ASD (m)	danger value
> 10 (outside buffer zone)	1	>3	low	> X (outside the buffer zone defined for each type of Infra)	1
<= 10 (In the buffer zone)	2	< 3	mediu m	< X (in the zone defined for each type of infra	2
	3		high		3
	4				4
	5				5

Based on the danger values of each of the five (5) parameters of Table 5, the possible maximum and minimum total danger values of the Fuel Reduction Map are:

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Maximum Fuel Reduction Map (FRM) danger value =14 (total of maximum values of each parameter =2 + 5 + 2 + 3 + 2)

Minimum Fuel Reduction Map (FRM) danger value = 5 (total of minimum values of each parameter = 1+ 1 + 1+ 1 +1)

The final FRM with Priority classes is created according to Tables 5 & 6 and based on the above minimum & maximum danger values.

Table 6: FRM priority classes (classification of FRM danger values)

FRM values	FRM priority class
5	4 (low priority)
6-8	3 (medium priority)
9-11	2 (high priority)
12-14	1 (very high priority)

Analyses for Level B

The methodology for Level B analysis is an extension of Level A, with a deeper focus on the intricate details of vegetation characteristics that could influence wildfire risks. This enhanced analysis is made possible through the use of Unmanned Aerial Vehicles (UAVs), which provide a bird's-eye view of the landscape and gather data that might not be visible or accessible from the ground.

- Height of Vegetation Near Infrastructure: UAVs can accurately measure the height of vegetation growing close to infrastructure such as power lines, buildings, and roads. This data is crucial because taller vegetation can pose a higher risk in the event of a wildfire, potentially leading to more extensive damage.

- Canopy Distance: The distance between the top of the vegetation canopy and the nearest infrastructure is another critical factor. UAVs help in determining this distance, which is essential for creating buffer zones that can slow down or stop the spread of wildfires.

- Additional Vegetation Characteristics: UAVs can also detect other important vegetation attributes, such as density, and moisture content. These factors can influence how likely it is for vegetation to ignite and how quickly a fire might spread.

- Acceptable Safety Distance (ASD): Based on the data collected, an Acceptable Safety Distance (ASD) is calculated for each type of infrastructure. This distance is the minimum required space between the infrastructure and the surrounding vegetation to maintain safety standards. The ASD is not a one-size-fits-all measurement; it varies depending on both the type of infrastructure and the characteristics of the nearby vegetation.

By combining these detailed layers of information, Level B analysis provides a comprehensive understanding of the potential wildfire risks associated with different types of vegetation and their proximity to various infrastructure. This allows for more informed decision-making when it comes to vegetation management and wildfire mitigation strategies.

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Homogeneous Territorial Class (HTC) calculation

Each parameter has been discretised according to the intervals shown in Table7, in order to obtain a limited number of classes. The spatial combination of these classes on a pixel-by-pixel basis provides a sort of landscape classification. Each combination generates a class representative of a particular combination of the parameters considered, defined as **Homogeneous Territorial Class** (HTC). The theoretical maximum number of **HTC** which can potentially exist is equal to the product of the number of classes of each considered parameter. This number corresponds, following the subdivisions shown in Table 3, to the product:

4 x 3 x 5 x 8 x 3 = 1440 HTC (theoretical value)

Table 7:Ranges for the subdivision into Homogeneous Territorial Classes (HTCs) for Prescribed Burning (according to PREFER project classification).

Elevation	Slope	Aspect	Fuel	Climate	Classes
< 100 m	< 5°	Zenith	Grassland vegetated by annual grasses and forbs	Lauretum hot subzone	1
100 – 500 m	5°- 25°	North	Sclerophyllous oakwood vegetation	Lauretum intermediate subzone	2
500 – 1000 m	> 25°	East	Grassland vegetated by perennial grasses	Lauretum cold subzone	3
> 1000 m		South	Broadleaved forests of Quercus ilex and suber		4
		West	Broadleaved forest		5
			Sparsely vegetated areas		6
			Transitional Woodland shrub		7
			Non forest class		8

2.3 Stakeholder Consultation

The realization of a focus group to investigate the issues of the ignition and propagation of wildfires and the necessary actions to be taken to prevent them required a preliminary phase of mapping, analysis, and identification of stakeholders and citizens' scientific networks.

In the demonstration area located in the central-western part of Sardinia (the municipality of Suni), since the ‘80s there has been a strong need to reduce wildfires and uncontrolled ignitions due to agricultural and agro-pastoral activities. In past years, pastoral burning practices, typically carried out for pasture renewal, were usually conducted in September, before the first autumn rains, in non-arable pastures characterized by superficial rocks and stones in the soil. However, in the '70s, pastoral fires were prohibited by law, and as a consequence, landowners started clandestinely igniting fires, leading to uncontrolled propagation, often turning pasture fires into large wildfires. To address these issues, a programme of controlled burning activities has been carried out by the Sardinia Forest Service since 2012, in collaboration with the municipal administration, breeders, and farmers in the area, with the aim of recovering ancient pastoral burning practices and limiting uncontrolled wildfires.

Starting from the analysis of this situation, the objectives of the Activity 2.1.1 and of the stakeholder consultation were defined as follows:

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- To study the awareness of local communities regarding wildfire risk issues and the potential of prevention approaches from different perspectives (environmental, health, economic, etc.).
- To understand the willingness of local communities to continue and expand fire prevention activities, mainly through controlled burning, and other strategies and policies defined among local communities and stakeholders (local, provincial, regional, national, EU) to sustain the multifunctional role played by active and modern agro-pastoral farms, better collaboration among economic operators, and better infrastructure.
- To assess and potentially increase the level of knowledge of prescribed fire use techniques by local communities.
- To estimate the awareness of the socioeconomic and environmental damages caused by uncontrolled fires under extreme weather condition days in the summer season.

Given the medium-long term characteristics of the wildfire regime, as well as the likely variations expected in the Mediterranean Basin in future years, key tasks include understanding the degree of knowledge of wildfire issues by local communities in the study area, as well as assessing the awareness of future challenges (climate change, land abandonment, increase in fuel load and continuity, WUI expansion, etc.) for the Agencies in charge of land policy and wildfire management. Moreover, central Sardinia in recent years has faced strong problems related to the increasing presence of specific detrimental insects/fungi/bacteria species, mostly related to massive land abandonment processes, and the increase in flammable fuel load and continuity. A future development of the use of prescribed fires includes the use of this tool for limiting the areas mostly affected by these diseases and managing abandoned lands to lower wildfire risk.

The area of Suni, though characterized by a limited number of inhabitants (about 1000), presents a good case of vitality. The inhabitants and economic operators participate and express themselves in decisions of community interest. This relationship among the population, local administrators, and Sardinia Forest Service led to the birth of the project on controlled burnings, arising from a specific need of the agro-sylvo-pastoral farms, which provided opinions and information on the ancient methods used to manage the landscape for fire prevention purposes. The vitality of the community is also expressed by a collaborative municipal administration and an association of volunteers (Compagnia Barracellare), ensuring fire prevention interventions and patrols, supporting firefighting operations, and participating in the drafting of prescribed fire plans. These aspects were considered in the preliminary phase of the analysis, which revealed the following main stakeholders in the study area:

- Economic operators engaged in agricultural and agro-pastoral exploitation of agricultural and rural areas in the municipality of Suni (medium-low relevance, high interest), and/or in neighbouring municipalities.
- Other economic operators interested in the protection of the environmental and social value of the area. To be identified (e.g., owners of bars, restaurants, third sector activities, bed&breakfasts, etc.) (medium-low relevance, high interest).
- Municipal administration engaged in controlling the territory and safeguarding people and the environmental and socio-economic heritage exposed to the risk of wildfires (high relevance, high interest).
- A volunteer association engaged in land control and fire prevention and, during the fire season, in patrolling and firefighting activities (high relevance, medium interest).

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Economic operators were engaged individually or by making use of producer associations that are well present in the area as well as in the rest of the region and engaged in agricultural development policy issues. The focus group was held in June 2023 and involved livestock farmers, people from the Forest Service and other institutions involved in wildfire prevention, volunteers, municipality administrators, and forest fire researchers. The participants were facilitated by ISIG and CNR and worked as group brainstorms, on the identification of obstacles and clustering of obstacles per thematic area. They identified the following aspects to evaluate for the implementation of prescribed fire and other prevention activities:

- Degree of cooperation of regional legislators on prevention issues.
- Availability of a defined framework for implementation of major prevention strategies.
- Evaluation of a balance between suppression and prevention.
- Complexity of authorization procedures.
- Impact of depopulation and abandonment of the rural areas.
- Impact of climate change and interaction with rural abandonment.
- Impact of the aging population.
- Impact of property fragmentation in relation to prevention intervention planning.
- Effectiveness and maintenance of fire breaks on private pastures and the impact on prescribed fire interventions.
- Impact of aging and reduction in the number of operators in charge of executing interventions.
- Evaluation of the aesthetic impact of interventions.

2.4 Expert Judgment

The FirEUrisk Questionnaire "**National Legislation on Forest Fire Prevention Linked to Critical Infrastructure"** addressed to consortium members, served as a mechanism for Expert Judgment by leveraging the specialized knowledge and experience of these members. As experts in their respective fields, consortium members are well-positioned to provide authoritative assessments on the effectiveness of national legislation and practices related to forest fire prevention and critical infrastructure. Their responses to the questionnaire contributed to a collective understanding of the current state of affairs, identified best practices, and highlighted areas needing improvement or further research. This experts' input is crucial for developing informed, evidence-based strategies and policies to mitigate the risks of forest fires associated with critical infrastructure. By participating in the questionnaire, consortium members effectively acted as Expert Judges, offering their insights to shape the future direction of fire management and prevention efforts.

The FirEUrisk Consortium Questionnaire was designed to gather comprehensive data on national legislation and the impact of critical infrastructure on forest fire prevention. Its purpose was to:

- Collect standardized data across different countries regarding wildfires linked to critical infrastructure.

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- Identify and analyze the types of critical infrastructure most frequently associated with wildfire ignitions.
- Review existing laws and regulations aimed at preventing forest fires, particularly those related to critical infrastructure.
- Assess the effectiveness of current legislative measures and identify challenges or gaps in the framework.
- Propose improvements and amendments to enhance the effectiveness of forest fire prevention efforts.
- Encourage sharing of best practices and successful initiatives that mitigate fire risks associated with critical infrastructure.
- Foster collaboration and suggest areas for further research to improve forest fire prevention and safety around critical infrastructure.

Respondents were asked to provide detailed information on annual wildfire statistics, types of critical infrastructure involved, existing legislative measures, their enforcement and effectiveness, and any gaps or challenges observed. The questionnaire also sought additional insights and recommendations for advancing forest fire prevention strategies. The structured approach aimed to support informed policy making and the development of robust, effective fire management practices.
The questionnaire is included in the ANNEX 1 of the current deliverable.

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3 Results

3.1 Current situation and trends of wildland fire ignitions

The escalating frequency and intensity of wildland fires necessitate a thorough understanding of their ignition patterns and the legislative frameworks that govern fire prevention, particularly in relation to critical infrastructure. The analysis of the FirEUrisk Consortium's comprehensive questionnaire on "National Legislation on Forest Fire Prevention Linked to Critical Infrastructure" provides an invaluable lens through which to examine the current situation and emerging trends in Europe. The completed questionnaires are included in Annex B (section 7.2).

3.1.1 Fire ignitions and trends in EU countries

The following table (Table 8) which is based on the first part of the analysis of the FirEUrisk Consortium Questionnaire "National Legislation on Forest Fire Prevention Linked to Critical Infrastructure" presents a comparative analysis of the causes of wildfires and their association with critical infrastructure across various European regions. This overview underscores the complex interplay between human activities, critical infrastructure, and natural causes in wildfire ignitions across Europe.

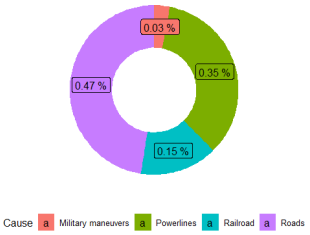
Table 8: Data on wildfires and critical infrastructure

Country / Region	Causes of wildfires last year/ last 5 years	Wildfires & critical infrastructure last five years
Portugal	Last year Natural causes (lightning): 2% Transport & Commun. - 7% Use of machinery: 5% Use of fire – 40% Arson – 28% Rekindling – 5% Other causes – 13%	About 7 % of all causes - mostly Power lines - Railways (sparks) - Road Vehicles - Road accidents
France	Data non-available to the public National data-base BDIFF : Accueil (agriculture.gouv.fr)	- Powerline are often involved in fire ignition during high wind period or heat wave - Fire along the railway transportation network are frequent, but less common than the freeway network which account for a large proportion of fires due to car fires or cigarettes. - Fires along railroads are often multi-sited, with each ignition point several hundred meters apart, making first-instance fire-fighting difficult.
Scotland	Non-available data It is considered that most wildfires in Scotland are caused by people: accidentally - e.g. campfires, BBQs, cigarettes, etc. and by 'managed' burns, when fire is used as a management tool and is part of grazing and hunting practices, much of which occurs in uplands and moorlands.	Possibly associated with the ignition of wildfires: - offshore oil and gas platforms, - the Grangemouth oil Refinery and petrochemical plant, - military communication facilities of Kinloss Barracks and Crimond in north east Scotland, - power stations (including one nuclear station in operation), electricity and gas sub-stations, mobile phone networks, - critical engineering facilities, numerous pipelines, especially onshore pipelines and terminals that

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		connect the north east of Scotland to its industrial central belt
Croatia	Non-available data Most fire ignitions are connected with human activities, particularly agricultural activities and lightnings.	small number of fires caused by power lines and a certain number, particularly in Split-Dalmatia County connected with sparking from the railways Links Fires caused by railway: 17.7.2010. - https://www.24sata.hr/news/vlak-je-naglo-zakocio-te-je-uz-tracnice-zapalio-travu-182560 1.08.2013 - https://www.vecernji.hr/vijesti/vlak-zapalio-novi-pozar-u-kastelima-gasila-ga-i-2-air-traktora-592852 17.08.2013 - https://www.tportal.hr/vijesti/clanak/crni-dim-nadvio-se-nad-splitom-gradani-se-zale-na-otezano-disanje-20130817/print 28.02.2019 - https://varazdinski.net.hr/vijesti/crna-kronika/3347869/pozar-kod-zeljeznickog-mosta-na-dravi-zapalila-se-sikara-i-trava/ Fire caused by power lines: 05.06.2011 - https://www.vecernji.hr/vijesti/zice-dalekovoda-zapalile-travu-pozar-gase-i-dva-kanadera-296758
Italy / **Regione Autonoma Friuli Venezia Giulia**	Detailed data available It must be said that often the actual cause of the genesis of a forest fire is difficult to attribute with certainty, and only when the specific trigger is sure it is indicated. For this reason, the statistics still offer a partial and non-exhaustive view.	Total of forest fires due to the presence of infrastructure: 4.48% - sparks due to friction of the wheels on the tracks: 4.04% - Fires caused by poor maintenance of power lines or the breakage and fall of conductors to the ground: 0.33% In previous statistics (since 1970), there were recurrences of fires generated by military ranges, this type of cause no longer occurs since 2017, also thanks to the regulations and prevention measures put in place.
Italy / **National**	Detailed data available – National database	24% of fire ignitions are located near road networks. The main reason for this is that malicious or negligent ignitions have higher probability to occur near road. A study of Fire Brigades reports that: 0.4% of events are due to trains (Sparks caused by the friction of wheels); 7.8% of events are due to cigarette butts (part of the 24% mentioned above); 0.8% of events are due to power line.

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Netherlands	Non-available data Statistics on wildfires are currently maintained by the CBS Natuurbranden - Centraal Bureau Voor de Statistiek. However, data on the ignition sources for many of these fires (which can be numerous depending on meteorological conditions, but small) are not often included.	Statistics with level of detail on ignition sources are not yet available
Finland	In Finland, the average area of fires is typically small, less than 1 hectare, but of course some bigger areas than 1 ha have also burned. The total area burned is less than 1000 ha. These are typically not attributed to critical infrastructure, and there is no any data available covering that information.	Nowadays the number of fires is around 2000 every year but the total area is still normally under 1000 ha. Very rarely critical infrastructure is affected. The area has diminished dramatically from 1950-1960 numbers https://yle.fi/a/3-12039884
Spain	The EGIF database has been temporally suspended and we have no data after 2016 EGIF (General Statistics of Wildfires) database from the MARM (Ministry of Environment and Rural and Marine). Reports of Wildfires of the Autonomous Communities. https://www.miteco.gob.es/es/biodiversidad/temas/incendios-forestales/estadisticas-datos.html Many fires are attributed to human causes, whether accidental or intentional. This includes negligence, agricultural burning, and arson	16655 Ignitions (2.89 %) (1998-2015)  https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-espanol-patrimonio-natural-biodiv/sistema-indicadores/06c-estadistica-incendios-forestales.html Campañas (miteco.gob.es) Campañas en medios de comunicación (miteco.gob.es) Efectos negativos sobre el PNB. Letra I (miteco.gob.es) https://www.miteco.gob.es/content/dam/miteco/es/biodiversidad/publicaciones/miteco-librolosincendiosenrednatura-pdfdigital2022_tcm30-550138.pdf
Greece	Non-available data A large number of fires in Greece are started by human actions, whether intentional or accidental. Common causes include negligence, such as improperly extinguished campfires or discarded cigarettes, and deliberate arson Greek Fire Service Database https://www.fireservice.gr/el/synola-dedomenon	
Cyprus	Detailed data provided by the database of the Fire Service http://www.fs.gov.cy/FS/fs.nsf/All/77906844334E0	Power cables is the only reported by the Forest Department as cause of wildfires related to critical infrastructure.

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	C6AC22585F800223100?OpenDocument Last year there were recorded 232 wildfires and 27 (12%) of those were cause by power lines resulting to approximate 83ha of burnt area (out of 1016.5459ha)	For instance, in a report available from the Forest Department for the years 2000-2021 5% (35 fires) of the wildfires are recorded to be cause by power cables. https://www.moa.gov.cy/moa/fd/fd.nsf/F430338BA7D4AC57C2257E5000330A18/$file/%CE%A3%CF%84%CE%B1%CF%84%CE%B9%CF%83%CF%84%CE%B9%CE%BA%CE%AC%20%CF%83%CF%84%CE%BF%CE%B9%CF%87%CE%B5%CE%AF%CE%B1%20%CE%B4%CE%B1%CF%83%CE%B9%CE%BA%CF%8E%CE%BD%20%CF%80%CF%85%CF%81%CE%BA%CE%B1%CE%B3%CE%B9%CF%8E%CE%BD%20%CE%B3%CE%B9%CE%B1%20%CF%84%CE%B7%CE%BD%20%CF%80%CE%B5%CF%81%CE%AF%CE%BF%CE%B4%CE%BF%202000-2021.pdf In another report in the media for the year 2022 7% (3) of the total recorded wildfires for the year are reported to be caused by power lines. https://www.kathimerini.com.cy/gr/kypros/edeixan-idi-ta-dontia-toys-oi-pyrkagies-ta-prwta-stoixeia-toy-2023-pinakes other links : https://newcyprusmagazine.com/forestry-department-cyprus-accuses-electricity-authority-cyprus-eac-responsible-summer-wildfires-paphos-forest-palaichori-area-inadequate-maintenance-outdated-uninsulated-wires/ https://www.offsite.com.cy/eidiseis/koinonia/telos-ta-gymna-kalodia-tis-aik-mesa-sta-dasi-tha-mpoyn-alla-me-monosi https://news.rik.cy/article/2023/7/25/se-kinetopoiese-oi-arkhes-kai-sten-kupro-gia-antimetopise-purkagion-upo-elegkho-e-purkagia-ste-gialia/ https://www.moa.gov.cy/moa/fd/fd.nsf/C7940ABF1C1A3D41C2257E5000330827/$file/Forest%20fire%20statistics%20for%20the%20period%202000-2021.pdf

Brief analysis on fire ignitions in EU countries

Wildfires in Europe present a multifaceted challenge, with diverse ignition sources contributing to their frequency and intensity. This brief analysis, based on the data provided by the FirEUrisk community, delineates the primary causes and implicates specific infrastructural elements in these events.

Portugal exemplifies a scenario where human activities, notably fire and arson, constitute major wildfire causes, overshadowing natural factors such as lightning. A noteworthy concern is the involvement of critical infrastructure in ignitions, particularly power lines, and railways, highlighting a nexus between modern infrastructure and wildfire risks. While **France**'s data lacks public accessibility, existing insights suggest that power lines play a significant role in wildfire initiation, particularly during high winds and heat waves. This suggests that environmental conditions exacerbate infrastructure vulnerabilities.

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Scotland attributes most of its wildfires to human activities, specifically managed burns employed for land management. This reflects a unique regional practice impacting wildfire dynamics, necessitating tailored management strategies.

In **Croatia**, similar to Portugal, human actions alongside natural causes like lightning are predominant in wildfire genesis. The specific mention of fires associated with power lines and railways underscores a common European challenge regarding infrastructure-related wildfires.

Italy's detailed records reveal that a minor yet significant portion of forest fires are attributable to infrastructure, with sparks from railway wheel friction and poorly maintained power lines as noteworthy causes. This insight is pivotal for targeted preventive measures in infrastructure maintenance and design.

In **Finland**, fire ignitions predominantly result in small-scale fires, with the average affected area being less than 1 hectare. These incidents are generally not linked to critical infrastructure, and there is a lack of data specifically correlating fires to such structures.

Countries like the **Netherlands, Spain, Greece**, and **Cyprus** predominantly report human-induced causes, ranging from accidental negligence to deliberate arson. This broad spectrum of human influence necessitates comprehensive public awareness and stringent law enforcement measures.

Recommendations

Targeted Infrastructure Safety Measures: Strengthen infrastructure maintenance, especially in high-risk areas, and employ advanced technologies like fault detection systems in power lines and railways to mitigate ignition risks.

Region-Specific Fire Management Strategies: Customize strategies to regional peculiarities, such as managed burns in Scotland and the unique challenges of Mediterranean climates.

Integrated Public Awareness Campaigns: Develop extensive educational programs addressing the spectrum of human-induced causes, emphasizing the severe consequences of negligence and arson.

Enhanced Data Collection and Sharing: Standardize wildfire data collection across Europe, ensuring comprehensive, accessible, and comparable datasets. This would facilitate better-informed strategies and cross-border cooperation.

Climate Change Adaptation Strategies: Recognize the exacerbating role of climate change in wildfire dynamics and incorporate climate resilience into wildfire management policies and infrastructure design.

Investment in Technological Innovations: Adopt advanced technologies for early detection and rapid response, such as satellite monitoring, AI-based predictive modeling, and drone-assisted firefighting.

To better support informed policy making for critical infrastructure assets related to wildfires, additional data will be required s follows:

- **Consistent and Detailed Data**: Standardized data on ignition sources, including specific human activities and infrastructure faults.
- **Impact Assessment**: Comprehensive analysis of the ecological, economic, and social impacts of wildfires.
- **Effectiveness of Current Measures**: Evaluating the impact of existing prevention and management strategies on wildfire reduction.

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After analyzing the questionnaires shared with the FirEUrisk community, we found that the causes of wildfires in Europe are complex and multifaceted. We noted a significant interplay between human activities, critical infrastructure, and natural factors. To tackle these diverse causes, we recommend adopting targeted strategies, enhancing data collection, and integrating technological advancements in wildfire management. These measures will help to prevent and manage future wildfires more effectively.

3.1.2 National Legislation and Regulations in EU

The following tables (Tables 9 & 10) which are based on the second part of the analysis of the FirEUrisk Consortium Questionnaire "National Legislation on Forest Fire Prevention Linked to Critical Infrastructure" outline the wildfire management laws and regulations across various countries, focusing on their scope, responsible authorities, effectiveness, challenges, and gaps. The tables highlight the varying degrees of legislative development and implementation challenges in managing wildfires and protecting critical infrastructure across these regions.

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Table 9: Existing laws and regulations on wildfires and critical infrastructure

Country/Region	Existing Laws and Regulations	scope of these regulations/Responsible Authorities	Effectiveness and Challenges
Portugal	Decree-Law 82/2021 of 13 October, which establishes the integrated management system for wildfires in the continental territory. https://www.pgdlisboa.pt/leis/lei_mostra_articulado.php?nid=3453&tabela=leis&so_miolo=	The Article 49º of Decree 82/2021, regarding the secondary network of fuel breaks, defines: 1 - The secondary network of fuel breaks... is developed in the surroundings: a) Of the road and rail network; b) Of the lines for the transportation and distribution of electric power and the transportation of gas and petroleum products; c) Of built-up areas; d) Of hotels, campsites, and caravan parks, leisure and recreational infrastructure and parks, business location areas, industrial establishments, establishments covered by Decree-Law No. 150/2015, of August 5, fueling stations, logistics platforms, and landfills; e) Of facilities for the production and storage of electric power and gas; f) Of infrastructure supporting the Integrated System of Emergency and Security Networks of Portugal (SIRESP).	The law is only partially complied with, especially along secondary roads. An estimation is: a) Of the road (50%) and rail network (90%) b) Of the lines for the transportation and distribution of electric power and the transportation of gas and petroleum products (90%); c) Of built-up areas; d) Of hotels, campsites, and caravan parks, leisure and recreational infrastructure and parks, business location areas, industrial establishments, establishments covered by Decree-Law No. 150/2015, of August 5, fueling stations (99%), logistics platforms, and landfills (90%); e) Of facilities for the production and storage of electric power and gas (90%); f) Of infrastructure supporting the Integrated System of Emergency and Security Networks of Portugal (SIRESP) (90%).
France	In accordance with Article L131-16 of the French Forestry Code, when there are woods and forests less than 20 meters from the boundary of a railroad or power line (Article L134-11), the infrastructure manager has the right to clear a longitudinal strip of undergrowth 20 meters wide from the outside edge of the track.	Concerning the railways, the law indicates to clear any vegetation 20 meters away of the track to prevent trees to fall on the railway. For industries, the defensible space should be 100 meters deep. Concerning the power line, technical rules are available in this link. The vegetation clearing depends on the voltage and location of power lines.	There are 3 main challenges : • Ownership of the land: the power network company don't own the land below the powerlines. As a result, the company may not be authorised to clear the land below the lines. • Cost. Clearing everything and maintaining clearance every year is too expensive to be affordable

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- Environmental constrain : suppressing all vegetation along the lines is not nature-friendly

Scotland	In March 2011, the Scottish Government published its first ever strategy for Critical Infrastructure Resilience (CIR) in Scotland – 'Secure and Resilient – A Strategic Framework for Critical National Infrastructure in Scotland.' The Fire and Rescue Framework for Scotland 2016 and the next, of 2022 (following public consultation), set out priorities and objectives for the Scottish Fire and Rescue Service (SFRS). SFRS has have a statutory duty, under the Fire Scotland Act (2005), The Fire (Additional Function) (Scotland) Order (2005) and others. The other regulations and those, specifically concerning the land use sector (important for Scotland) and on wildfires include: Fire and Rescue Service Wildfire Operational Guidance, 2013; Wildfire prevention, the Scottish Forestry which advises that managers should plan for forest resilience whilst considering the risk from fire. There are also relevant regulations at the UK level e.g., the UK Forestry Standard. Guidance is provided in the UK Forestry Commission (2014) Practice Guide 22: Building Wildfire Resilience into Forest Management Planning and in the FC regulation on wildfire prevention. The Information Note supports forest owners, planners, and managers in Scotland to implement this guidance. The wildfire prevention by the Forestry and Land Scotland is executed in collaboratively with the Scottish Fire and Rescue Service and the Scottish Wildfire Forum. The Wildfire Strategy of Scottish Fire and Rescue Service, their Guidance, 2023 and leaflets are important in preventing forest fires. Also, Preventing Wildfires on Agricultural Land document offers practical strategies and downloadable tools to help take steps to reduce the risk of wildfires. For example, controlled burns in compliance with the Muirburn Code and under Fire and Rescue Service expert supervision can be an effective tool.	The scope includes the issues associated with the prevention of wildfires caused by the critical infrastructure. As to the types of Critical National Infrastructure, it consists of the following Sectors: Chemicals, Civil Nuclear, Communications, Defence, Emergency Services, Energy, Finance, Food, Government, Health, Space, Transport and Water. Several sectors have 'sub-sectors'. The Fire and Rescue is a sub-sector of Emergency Services. A wide range of organisations are responsible for the resilience of critical sectors, including the owners and operators, emergency services and local and central governments. Offshore oil and gas platforms, the oil refinery and petrochemical plant, power stations and pipelines are of special attention.	The Critical National Infrastructure (CNI) fire safety approach is in use and the sector has excellent global reputation as they constantly use innovative technology and science to keep all, as safe as possible. However, if the hazard is special and the infrastructure critical, there is a case for the constant monitoring of the fire suppression systems that aim to deliver the protection (Hunter, 2022). Inspection should also include an evaluation that the extinguishing system continues to provide adequate protection for the risk. In CNI, in Scotland, the technical means and capabilities for doing it exist, but a challenge is to fully utilise these and advance further the technology, including digital/AI (subject to regulations, financial and other constraints that may come up). Greater focus on the human element, including social capital and innovation, is crucial for fire prevention. In Scotland, human-induced wildfires, often accidental or for land management, are prevalent. Climate change will likely alter fire causes, necessitating updated regulations to address the expected increase in fires due to warmer summers and more frequent extreme events.
Croatia	There are very well-developed legislative concerning firefighting. The base documents are:	On page 6 of Program of activities in the implementation of special fire protection measures of interest to the Republic of Croatia (https://hvz.gov.hr/UserDocsImages/dokumenti/Program%20aktivn	While assessing effectiveness presents challenges, the well-structured fire prevention measures and firefighting services have led to a notable reduction in both the extent

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	• Low on Firefighting (in Croatian: Zakon o vatrogastvu) from 2019 - https://narodne-novine.nn.hr/clanci/sluzbeni/2019_12_125_2486.html • Low on Fire Protection (in Croatian: Zakon o zaštiti od požara) from 2010 - https://narodne-novine.nn.hr/clanci/sluzbeni/2010_07_92_2588.html According to them every year a special legal document is published named • Program of activities in the implementation of special fire protection measures of interest to the Republic of Croatia (in Croatian Program aktivnosti u provedbi posebnih mjera zaštite od požara od interesa za Republiku Hrvatsku) – document for 2023 is on this link - https://hvz.gov.hr/UserDocsImages/dokumenti/Program%20aktivnosti/191%20-%209%20Program%20aktivnosti%202023..pdf It defines everything connected with fire protection measures.	osti/191%20-%209%20Program%20aktivnosti%202023..pdf) in 8a it is written: 8. a) Local self-government units, public institutions of national parks and Hrvatske šume d.o.o. are obliged, in cooperation with the competent county/City of Zagreb fire brigades, to update, that is, to create monitoring, guarding and patrolling plans and to implement the prescribed fire protection measures in endangered areas, buildings and areas along railway and road routes for their area of responsibility. The aforementioned entities are required to pay particular attention to the maintenance of access roads for emergency vehicles to critical infrastructure (railways, highways, power plants, water pumping stations, forests, gas pipelines, oil pipelines, transmission lines, etc.).	of burned areas and the frequency of wildfires in 2003. This suggests that the current laws and legislative frameworks are quite effective.
Italy / National	LEGGE 21 novembre 2000 , n. 353: Legge-quadro in materia di incendi boschivi. Art. 3. Piano regionale di previsione, prevenzione e lotta attiva contro gli incendi boschivi. The regions approve the regional plan for the programming of forecasting, prevention and active fighting activities against forest fires, on the basis of guidelines and directives approved, within sixty days from the date of entry into force of this law. L.R. (Legge Regionale) 28 Ottobre 2002, n. 39: Norme in materia di gestione delle risorse forestali Art. 93. (Misure per la prevenzione degli incendi nelle aree boscate) Fire prevention regulations mandate year-round fire bans and require the creation of firebreaks in high-risk areas. Before the	The public bodies competent for the management of road (municipalities, provinces, regions may stipulate agreements with the owners or in any case holders of the adjacent and contiguous areas for the purposes of management and maintenance of the relevant area. Electric power operators are in charge of cleaning areas around high voltage power network. Train operator (e.g. Tranitalia) are in charge of cleaning the area around railways.	current laws and regulations do not include penalties in case of non-compliance with the requirements. Then, among challenges and/or gaps we can mention: - inadequate enforcement mechanisms; - insufficient monitoring of the implementation of the prescriptions

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	fire season, a 5-meter firebreak must be established next to roads and forests, and a 20-meter clearance around railways and power lines. Electrical substation managers must clear a 10-meter radius of flammable vegetation. Debris from these clearances can be chipped or removed. Authorities may also collaborate with landowners for maintenance purposes. Art. 95 (Cautela per l'impianto di fornaci e fabbriche nei boschi. Discariche) Factories and landfills posing a fire risk cannot be established in or near woods without approval from the relevant authority, which will also stipulate necessary fire prevention measures for the area. mechanism of no compliance LEGGE 21 novembre 2000 , n. 353: Legge-quadro in materia di incendi boschivi. Art. 3. Piano regionale di previsione, prevenzione e lotta attiva contro gli incendi boschivi In the event of non-compliance by the regions, the Minister delegated for the coordination of civil protection, using the Civil Protection Department, the National Fire Brigade and the State Forestry Corps, having consulted the Unified conference, prepares, also at an inter-provincial level, emergency.		
Netherlands	Although interest is increasing in wildfires in the Netherlands, conservation and restoration of natural areas are largely the focus of relevant legislation and are often not tailored with principles of landscape fire management in mind. Safety Region's Act (2010)-- replaces the Disaster and Heavy Accidents Act, the Act on Medical Assistance in Times of Disaster and the Fire Service Act of 1985. Establishes the 25 safety regions for the NL through which wildfire response is managed. Since 2016 the Dutch fire department is working on the 'Visie Natuurbrandbeheersing', which will become an integrated approach to prevent and combat future wildfires (IFV, 2017).	No formal wildfire policies have been identified. Some governmental organizations, such as the Ministerie van Landbouw, Natuur en Voedselkwaliteit, rather offer advice on create more fire-smart landscapes. There is some effort to move away from a fire repression paradigm and towards preventive management strategies.	As the data does not currently allow us to make a connection with critical infrastructure and fire and current laws and regulations do not account for wildfire, improvement/ awareness is needed.

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	Prior to 2002, the 'Bosbrandverordening' program (Jansen & Oldenburger, 2006) actively promoted landowners to make their areas less vulnerable to wildfires. The Bosbrandverordening focused on making forest more reachable for firefighters and tried to reduce the possibility that a forest floor fire could spread into the crowns of the trees and hereby become uncontrollable, by removing dry wood and preventing the stacking up of woodpiles.		
Finland	Forest Act (62/2017) Rescue Act (379/2011) Land Use and Building Act (132/1999) Environmental Protection Act (527/2014) Government Decree on Forest Fire Protection (684/2015)	While these laws and regulations do not explicitly target forest fires related to critical infrastructure, they establish a framework for managing forest fires and protecting public safety, including critical infrastructure assets. Local authorities, forestry agencies, and other stakeholders are responsible for implementing these regulations and taking appropriate measures to prevent forest fires and mitigate their impacts on critical infrastructure. The mechanisms involved are: Inspections and Monitoring, Permitting and Licensing,Public Awareness and Education, Coordination and Collaboration, Enforcement Actions and Penalties, Emergency Response and Crisis Management, Legal Proceedings Overall, the enforcement of regulations aimed at preventing forest fires and protecting critical infrastructure in Finland involves a combination of proactive measures, public engagement, enforcement actions, and emergency response efforts to minimize fire risks and ensure public safety.	Overall, while Finland has comprehensive laws and regulations aimed at preventing forest fires and protecting critical infrastructure, their effectiveness ultimately depends on robust enforcement, proactive preventive measures, stakeholder engagement, and adaptability to evolving challenges. Continuous evaluation and refinement of regulations based on lessons learned from past experiences and emerging risks are essential for enhancing their effectiveness in the long term. Effective coordination and collaboration are crucial for mitigating fire risks to critical infrastructure. Strengthening enforcement mechanisms, increasing inspection frequency, and imposing stricter penalties for violations can enhance compliance with fire prevention requirements.The current legislative framework may not adequately address the evolving risks and vulnerabilities associated with climate change impacts on critical infrastructure.
Greece	In Greece, the legal framework aimed at preventing forest fires, especially in relation to critical infrastructure such as power lines, includes the following (https://civilprotection.gov.gr/sites/default/files/2023-04/Εγκριση%20και%20αποστολή%205ης%20έκδοσης%20Γενικού%20Σχεδίου%20Δασικών%20Πυρκαγιών%20-%20ΑΔΑ%20ΡΣΛΘ46ΝΠΙΘ-ΝΛ5.pdf) : 1. The Forest Law (Law 998/1979) which, although it allows for certain activities within forested areas, includes strict regulations and conditions to ensure the protection of forests from fire risks originating from power lines and other infrastructural works.	The law is applied under the auspices of the Greek Civil protection (General Secretariat) and the Hellenic Fire Service legal and administrative mechanism. The scope of these regulations covers high-voltage power lines with required clearances of 15 meters on each side for lines with a voltage of 150 kV, and 20 meters for lines with a voltage of 400 kV. The regulations apply to both public and private land, with mandatory compliance by the power transmission companies. These preventive measures are required to be executed with guidance from the Fire Service and after obtaining necessary permits from forest authorities. Specific preventive measures mandated by these regulations involve	The law is quite recent and its effectiveness can't be assessed at this stage. The main gap is a codification of the legislation regarding forest fire related laws, regulations, decrees, directives etc that would facilitate the coordination, control and monitoring of the fire prevention activities by the all the relevant and involved authorities and organizations.

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	2. Law 4662/2020, particularly Article 53B, introduced specific provisions for the maintenance of safety zones along electricity transmission lines. This involves the clearance, pruning, and removal of trees and vegetation within a specified distance from the power lines to create firebreaks, ensuring that vegetation does not come into contact with power infrastructure and potentially ignite a fire. 3. In Greece, the national law regarding the prevention of forest fires specifically related to critical infrastructure, such as power lines, is included in the broader context of wildfire management policies. The key legislation is part of a comprehensive wildfire management plan known as "ΙΟΛΑΟΣ 2" (5th Edition 2022) which outlines a variety of strategies and actions to address forest fires. This includes the identification of fire risk areas, the role of critical infrastructure in fire prevention, and the mechanisms in place for managing and mitigating risks associated with wildfires.	maintaining clear zones around power lines, implementing vegetation management strategies to prevent contact with electrical infrastructure, and ensuring the readiness of power lines and related equipment to withstand fire-related risks. In the case of identified high-risk areas, there are additional measures such as increased surveillance and the use of advanced technologies to monitor the conditions around power lines. The enforcement of these preventive strategies falls under the purview of various authorities, including but not limited to, the General Secretariat for Civil Protection (Γενική Γραμματεία Πολιτικής Προστασίας), the Hellenic Fire Service (Πυροσβεστική Υπηρεσία), and the organizations responsible for the maintenance and operation of the power grid infrastructure. These entities coordinate to ensure that the necessary preventive actions are taken and that emergency protocols are in place in the event of a wildfire. This plan outlines a multi-tiered approach to managing forest fires, emphasizing a synergy between prevention, immediate response, and recovery efforts. Furthermore, it acknowledges the significance of collaboration between various agencies and stakeholders to effectively manage and mitigate the risks posed by wildfires to critical infrastructure and the environment .	
Spain	All relevant laws and regulations can be found in: https://www.mapa.gob.es/en/desarrollo-rural/legislacion/leg-espanola-forestal-incendios.aspx BOE-A-1973-208 Decreto 3769/1972, de 23 de diciembre, por el que se aprueba el Reglamento de la Ley 81/1968, de 5 de diciembre, sobre Incendios Forestales Forest laws are the competence of Autonomous Communities, 17 in Spain, as political units that jointly form the State, Spain. That makes for relevant differences in the way forest fires and management are organized, and regulations for infraestructures in terms of fire prevention. General provisions on wildland fires: Ley 43/2003, de 21 de noviembre, de Montes https://www.boe.es/buscar/pdf/2003/BOE-A-2003-21339-consolidado.pdf	The above-mentioned laws and regulations describe preventive measures, actions and sanctions on roads and power lines. In general terms, vegetation clearance is required at set distances from roads according to their order of importance, or under power lines depending on risk of tree falling, there are safety corridors and obligatory clearance distances. For train infrastructure, the situation is similar (there are corridors and regulations to treat the herbaceous vegetation on the corridor), but older local lines (the whole secondary network, not the primary high-speed network) have suffered from lack of maintenance due to financial cuts in budgets and personnel. No adequate maintenance of the stopping devices and of the rail is being performed. No consequences are apparent, nor enforcement is in place. Many stations are closed and abandoned. Economic fines, social responsibility and criminal charges. Generally, whoever is responsible for a fire should pay the damage, if identified in a technical and legal process (after fire investigation). Most times,	Ignition trends seem stable, but they are not decreasing as they should in application of the measures, since many are lacking. Control of vegetation along thousands of kms of power lines, railways and roads is complicated, and procedures are not effective when vegetation growth rates are not considered by depleted public services. Many operations belong to private power or railway companies, and they do not invest in prevention. Dispersion of designs and regulations across 17 CCAAs, lack of funding and personnel. Lack of directives to private companies. There is an anual Plan for fire prevention in RENFE (now ADIF), they added in 2005 an Extraordinary Plan for fire prevention in the line and surrounding terrain. It was a good

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	The Autonomous Communities will regulate in forest and nearby areas all activities that can rise fire risk and will establish safety regulations aplicable to buildings, operations, power instalations and transportation networks in forest areas and their surroundings, when these activities can increase fire risk, or be affected by fires. Ley 7/1985, de 2 de abril, Reguladora de las Bases del Régimen Local assigns rights (competences) to townships for prevention and suppression. https://www.boe.es/buscar/act.php?id=BOE-A-1985-5392 Real Decreto-ley 15/2022, de 1 de agosto, was devoted to urgent measures in forest fires matters. https://www.boe.es/buscar/act.php?id=BOE-A-2022-12926 An exemple of criteria for the design and maintenance of forest roads as fire prevention infrastructures in CCAA Valencia can be found in: https://cjusticia.gva.es/documents/162905929/163206728/NT+Viales+forestales+%289%2C7Mb%29/5996f665-3fd2-46ed-a8e6-99f5e953576f An exemple in Catalonia can be found here: DECRETO 130/1998, de 12 de mayo, by which measures of fire prevention are established in areas of influence of roads. http://www.carreteros.org/ccaa/legislacion/carreteras/cataluna/otras/d130_1998 .pdf Actions (vegetation clearance) under power lines by the State power company (CEE) are described here: https://www.ree.es/en/sustainability/the-natural-environment/fire-prevention/gallery-fire-prevention .	there are no consequences.	inittiative, but did not work for lack of funding. Sometimes trafic is interrupted because of fire risk.
Cyprus	The only law available (Οι περί Δασών (Άδειες, Χρήση Δασικών Δρόμων και Εξαγωγή Δασικών Προϊόντων) Κανονισμοί του 2012) (The Forestry (Permits, Use of Forest Roads and Export of Forest Products) Regulations of 2012) states the procedures	Due to the recent wildfires caused by power cables it has been decided by the Cypriot government that all the power cables passing through forest areas to be covered with special insulation material. To identify these areas and organise the relevant actions it has been	There are no laws in place A relevant legislation should be established

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for applying for permit in order to perform any actions inside the boundaries of a forestry area inlcuding among others cutting wood, setting up a camping area, performing car racing. The permisions and terminations of those is under the responsibility of the Director of the Forest Department.
https://www.moa.gov.cy/moa/fd/fd.nsf/all/B075B096E31148A8C225814000428970/$file/%CE%9F%CE%99%20%CE%A0%CE%95%CE%A1%CE%99%20%CE%94%CE%91%CE%A3%CE%A9%CE%9D%20%CE%9A%CE%91%CE%9D%20133-2012.pdf?openelement

decided by the Minstry of Argiculture to establish workign groups with representatives from the ministry, the EAC-national electricity provider, forest departnet and fire brigade.
https://www.kathimerini.com.cy/gr/kypros/systasi-monimis-omadas-ergasias-gia-meiosi-kindynoy-pyrkagias-apo-kalwdia

https://news.rik.cy/article/2023/8/5/ephikte-e-antimetopise-ton-problematon-apo-ta-gumna-kalodia-delonoun-aek-kai-tmema-dason/

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Table 10: Gap Analysis on wildfires and critical infrastructure

Country/Region	Gap Analysis
Portugal	The main difficulty is the rapid growth of vegetation, especially herbaceous plants, between April and July. The legislation obliges management until 15Apr, but then, when it rains, the herbaceous vegetation grows back. This leads not only to very high costs and a lack of labour for the volume of work.
France	Since it is too difficult, too expensive and not nature-friendly to clear the vegetation everywhere along the powerlines, railways, and so on, priority areas should be clearly evaluated (risk analysis methods) and divulgated to network operators. This priority mapping could be done : • by the government when declining the fire risk planification at local level • or by the operators supported by expert consultant *potential amendments or new regulations* Mapping the priority areas Tax credit for individuals for expenses incurred in clearing undergrowth. Compulsory deductible in insurance contracts for non-compliance with legal brush clearance obligations, and doubling of the maximum amount of this deductible.
Scotland	In Scotland, offshore oil and gas platforms, the oil refinery and petrochemical plant, power stations and numerous pipelines are objects of critical infrastructure that need special attention. Scotland does not routinely investigate the cause of wildfire ignitions and has no fire investigators qualified in this specialist skill. *potential amendments or new regulations* Currently, the UK private sector constitutes 96% of all expenditure on tackling fires. More is to be done in the public sector, including financial allocations to enhance the effectiveness of forest fire prevention efforts, and concerning multi-level governance (e.g. by promoting public-private partnerships, encouraging social innovation, etc.). Capacity building, social learning and exchanging of best practices and lessons learned are to be promoted (using various policy/governance instruments, including regulative.
Croatia	The legislation is generally effective, yet there is always room for enhancement, as evidenced by the evolution of the Program of Activities over time. For instance, a few years back, monitoring was limited to human observation; however, recent updates have expanded this to include video surveillance, reflecting a progressive approach to legislative adaptation
Italy / National	The introduction of a mechanism of monitoring of the compliance of the prescriptions, based even on satellite images, concerning the cleaning of the band around the infrastructure. *potential amendments or new regulations* For new installations of critical infrastructure, evaluating their locations by considering potential wildfire hazard (e.g.: by fire spread modeling or considering historical events) and vulnerability of the area. Promoting the building of firebreaks and fuel breaks for both a more effective control of wildfire spread and behavior and to have safe areas and anchor points from which suppression operations can be carried out safely. Better care should be taken in planning and maintaining the local road network, as well as in creating databases that can inform fire managers about the potential or limitations of given roads for terrestrial forces (e.g.: trucks cannot be used in specific roads).

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For some infrastructure (e.g.: wind farms), the operational potential of aerial firefighting forces is largely limited for safety reasons; under these conditions, to carry out ground operations in safe conditions, appropriate road networks should be designed and guaranteed in the long term (e.g. avoiding narrow or closed roads or risk of entrapments).

Netherlands	Recommended that legislature set regulations on the use of groundwater during drought periods and develop infrastructure for the storage of excess water for fire response. *potential amendments or new regulations* -More research needed on the proximate causes of ignitions, evacuation planning in the event of fires, water retention and storage infrastructure to fight wildfires in periods of drought, methods to increase the water table in agricultural areas which experience significant draw down in drought periods. -Nature, biodiversity restoration initiatives should include impacts on fire risk of their actions. These could include using native species, restoring wetlands, creating vegetation gaps, and avoiding needle leaf trees. -In general, awareness of wildfire risk should be increased for visitors to and owners of natural areas in the Netherlands.
Finland	Implementing standardized procedures and requirements for conducting comprehensive fire risk assessments specifically tailored to critical infrastructure could significantly improve preparedness and resilience. Creating a centralized coordination mechanism tasked with overseeing and coordinating efforts to protect critical infrastructure from forest fires could streamline communication, resource allocation, and decision-making processes.
Spain	Coordination between CCAAs in technical specifications, mainly for roads, railways and power lines. -Enforce more funding from private companies in adequate maintenance of their transportation networks. -Nobody pays for the damages caused. -There are not courts of law demands against the causing people. No demands from insurance companies who only seek to settle funds to satisfy their clients for damages. -Colateral damages are not valued/estimated and few receive subsidies. -In Spain very few judicial processes tackle negligence from agriculture, civil society, forestry, harvesting or uses of the forest when they produce a large fire. -There are not robust plans for educating or informing society on large fires, or a fire culture that makes people understand that sometimes fire is out of suppression capacity, and will keep burning areas. -Little awareness that some scenarios lead to imposible situations for extinction, that will cause irreparable damage. *potential amendments or new regulations* -Joint CCAA technical specifications and regulations for supervision/monitoring of vegetation conditions based on new RS sources, available lidar data, for instance. Regulations should be enforced through fines or administrative action. -Spatial optimization of maintenance work locations based on environmental/vegetation conditions under limited funding.
Greece	Develop a well organized codification of the existing legislation defining actors, responsibilities, obligations and needs for cooperation and coordination between involved stakeholders. *potential amendments or new regulations* Coordination between legislation concerning critical infrastructure, forest policies and civil protection policies in order to be compatible and complementary between them.
Cyprus	*potential amendments or new regulations* Legislation for critical infrastructure & wildfires should be established

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Comprehensive Analysis and Policy Recommendations for Fire Management and Critical Infrastructure

Based on the feedback received by the FirEUrisk community, we summarize per country the legislative and institutional approaches adopted by various European countries and governments to mitigate wildfire risks, particularly those associated with critical infrastructure. Furthermore, we comment on the effectiveness and challenges of the approaches adopted and provide some general recommendations within the scope of the FirEUrisk project.

Portugal

Legislation: Decree-Law 82/2021 mandates fuel breaks around infrastructure and populated areas.
Effectiveness and Challenges: Partial compliance, especially along secondary roads. Rapid post-rain regrowth from April to July poses maintenance challenges, leading to high costs and labor shortages.
Recommendations:

- ✓ Implement more stringent monitoring and enforcement of compliance, especially along secondary roads.
- ✓ Develop innovative, cost-effective vegetation management techniques to address rapid regrowth issues.
- ✓ Explore the use of technology, such as drones, for monitoring and maintenance of fuel breaks.

France

Legislation: French Forestry Code mandates vegetation clearance around railroads and power lines.
Effectiveness and Challenges: Land ownership issues, high costs, and environmental concerns.
Recommendations:

- ✓ Conduct risk-based prioritization of areas for vegetation clearance.
- ✓ Implement tax incentives and insurance penalties to encourage compliance.
- ✓ Enhance public-private partnerships for effective land management and cost-sharing.

Scotland

Legislation: Critical Infrastructure Resilience strategy, various wildfire prevention guidelines, and regulations.
Effectiveness and Challenges: Utilizing technological advancements and addressing human factors.
Recommendations:

- ✓ Increase public sector investment in fire prevention efforts.
- ✓ Enhance collaboration between public and private sectors.
- ✓ Foster social learning and knowledge exchange to improve fire management practices.

Italy

Legislation: Regional plans for forest fire prevention and response.
Effectiveness and Challenges: Lack of penalties for non-compliance.
Recommendations:

- ✓ Introduce monitoring mechanisms for compliance, potentially using satellite imagery.
- ✓ Assess new infrastructure projects for wildfire risks.
- ✓ Improve road networks for firefighting access and consider aerial firefighting limitations.

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Croatia

Legislation: Firefighting Law (2019) and Fire Protection Law (2010).

Effectiveness and Challenges: Systematic fire prevention measures have reduced wildfire occurrences since 2003.

Recommendations:

- ✓ Continue updating and evolving fire prevention measures, such as integrating video surveillance.
- ✓ Strengthen coordination between local authorities and fire brigades for enhanced surveillance and response.

Netherlands

Legislation: Safety Region's Act and 'Visie Natuurbrandbeheersing' initiative.

Effectiveness and Challenges: No formal wildfire policies focusing on critical infrastructure.

Recommendations:

- ✓ Develop specific regulations for the use of groundwater during droughts.
- ✓ Incorporate fire risk considerations into nature restoration projects.
- ✓ Increase public awareness of wildfire risk

Spain

Legislation: Forest laws are the competence of Autonomous Communities, 17 in Spain, as political units that jointly form the State, Spain. That makes for relevant differences in the way forest fires and management are organized, and regulations for infrastructures in terms of fire prevention.

General provisions on wildland fires: Ley 43/2003, de 21 de noviembre, de Montes

Effectiveness and Challenges

- ✓ Coordination between CCAAs in technical specifications, mainly for roads, railways and power lines.
- ✓ Very few judicial processes tackle negligence from agriculture, civil society, forestry, harvesting or uses of the forest when they produce a large fire.

Recommendations

- ✓ Joint CCAA technical specifications and regulations for supervision/monitoring of vegetation conditions based on new RS sources, available lidar data, for instance. Regulations should be enforced through fines or administrative action.
- ✓ Spatial optimization of maintenance work locations based on environmental/vegetation conditions under limited funding.

Cyprus

Legislation: Law for forests and relevant regulations (ΚΔΠ 133/2012)

Effectiveness and Challenges: No formal legislation focusing on wildfires and critical infrastructure.

Recommendations:

- ✓ Establishment of legislation for wildfires and critical infrastructure

Greece

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Legislation:

Effectiveness and Challenges: No formal wildfire policies focusing on critical infrastructure.

Recommendations:

- ✓ Development of a well organized codification of the existing legislation defining actors, responsibilities, obligations and needs for cooperation of the stakeholders
- ✓ Coordination between legislation concerning critical infrastructure, forest policies and civil protection policies

Gap Analysis and Future Directions

In the countries that have been examined, there is a clear attempt to establish laws and regulations that deal with fire safety measures, particularly for critical infrastructure. Nevertheless, there are still gaps in compliance, enforcement, and the utilization of advanced technologies. Some of these gaps are mentioned below:

1. Standardized Monitoring and Reporting: Establish standardized mechanisms for monitoring and reporting compliance with fire safety measures across EU nations.
2. Technological Integration: Integrate modern technologies such as AI, remote sensing, and drone surveillance for effective monitoring and management of wildfire risks.
3. Cross-sector Collaboration: Enhance collaborative efforts between governmental bodies, private sector, and local communities for comprehensive wildfire management.
4. Public Awareness and Education: Implement extensive public awareness campaigns to educate on wildfire prevention, especially in areas surrounding critical infrastructure.
5. Adaptation to Climate Change: Update fire safety strategies to consider the impacts of climate change, including altered fire seasons and patterns.
6. Research and Innovation: Encourage research into new and cost-effective methods for vegetation management and fire prevention, tailored to each region's unique environmental conditions.

After making considerable strides in legislating fire safety measures around critical infrastructure in the EU, it is important to continue making efforts to address compliance, technological integration, and adaptation to changing environmental conditions. To further these efforts, increased cross-sector collaboration, public awareness, and ongoing legislative adaptation are crucial.

3.2 FirEUrisk Framework for Reducing operations-based fire ignitions

The results of the operations-based fire ignitions reduction framework, reducing which was developed within the context of FirEUrisk activity A2.1.2, are as follows:

- ✓ Advanced Methodologies for Risk Mapping
  Utilize cutting-edge airborne sensing technologies, including satellite imagery and UAVs, to identify high-risk areas along linear infrastructure.
- ✓ Fuel Management Prioritization Rules
  Develop criteria to prioritize fuel management efforts in areas surrounding power lines, roads, and railroads, informed by risk identification and fire incident data.

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- ✓ Specifications for Risk Reduction Treatments
  Establish clear specifications and requirements for treatments aimed at mitigating fire risks associated with operational activities linked to infrastructure.
- ✓ Operational Mapping for Fuel Treatment (Fuel Treatment Priority Map)
  Conduct comprehensive mapping to determine fuel treatment priorities near critical infrastructure within FirEUrisk Pilot Sites, covering the following aspects:
  - Total area (in hectares) designated for each fuel treatment priority level, both overall and within individual forest management units.
  - Integration of physical characteristics such as topography and fuel conditions within Homogeneous Territorial Classes (HTCs) to aid in selecting appropriate fuel treatment methods.
  - Assessment of fire behavior characteristics, including Rate of Spread (ROS) and Fireline Intensity (FLIN), for each HTC and forest management unit.

Examples of maps created by implementing the framework in the Portuguese Pilot Site (PS2) are shown below.

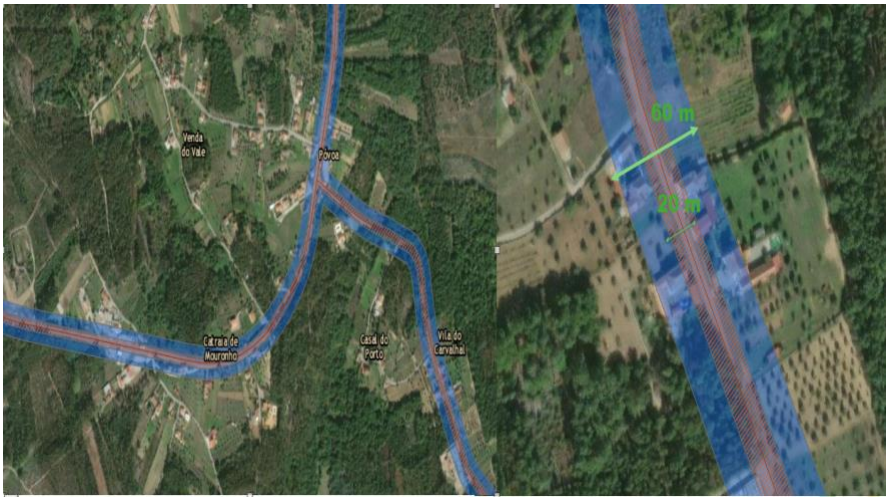


*Figure 1: Zone of analyses around networks & point assets/ Acceptable Safety Distance (ASD) for each type of network **& asset** (FirEUrisk Task 2.1/Activity 2.1.2, results of analyses for PS2)*

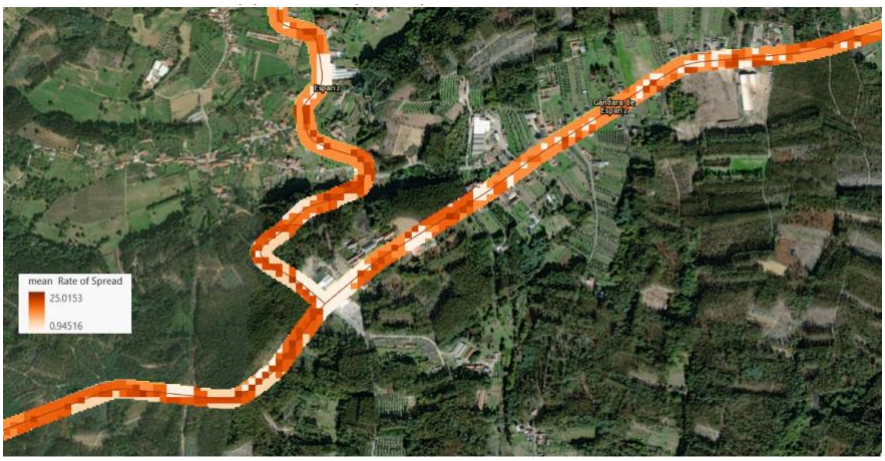


Figure 2: Estimation of Rate of Spread under a selected weather scenario for the PS (FirEUrisk Task 2.1/Activity 2.1.2, results of analyses for PS2)

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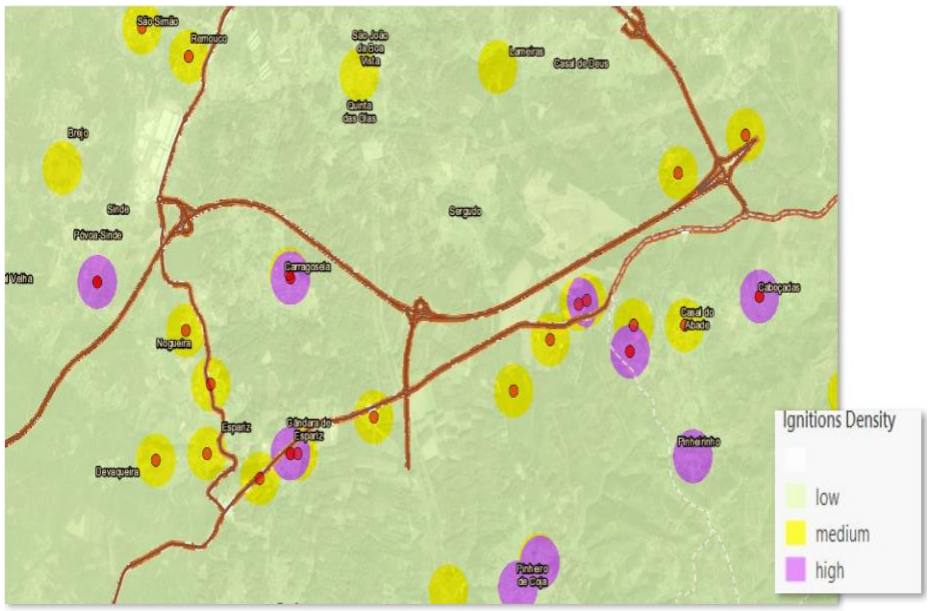


Figure 3: Ignitions Density map (ID) based on operations-based past-fire ignitions (FirEUrisk Task 2.1/Activity 2.1.2, results of analyses for PS2)



Figure 4: Fuel Treatment Priority map (FirEUrisk Task 2.1/Activity 2.1.2, results of analyses for PS2)

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3.3 Main drivers and challenges of wildland fire ignitions

Wildland fire ignitions are influenced by various drivers, including climate change, land use and management practices, and socioeconomic factors. Addressing the challenges associated with data availability and quality, prevention and mitigation aspects, interagency coordination, and environmental considerations is crucial for effective fire management. By understanding these drivers and challenges, stakeholders can work together to develop comprehensive strategies that prioritize prevention, early detection, and sustainable mitigation measures to mitigate the impact of wildland fires on communities and ecosystems. In Europe, especially in the Mediterranean basin, most fires are human-caused. Proximity to transport networks and urban or recreational areas are significant factors. Increased Human Activity: The WUI is characterized by increased human presence and activity, which can lead to more accidental ignitions from sources like campfires, smoking, and machinery [14].

3.3.1 Main Drivers of Wildland Fire Ignitions

Climate Change

Climate change plays a significant role in increasing the frequency and intensity of wildland fire ignitions. Rising temperatures, prolonged droughts, and shifts in precipitation patterns create favourable conditions for fire outbreaks. Higher temperatures accelerate evaporation, drying out vegetation and increasing its flammability. Moreover, climate change alters wind patterns, creating stronger and more unpredictable winds that can quickly spread wildfires.
Climate change has led to more extreme weather conditions in Europe , such as droughts and heatwaves, which can dry out vegetation and make the WUI more susceptible to ignitions [3].
Over 95% of fires in Europe are caused by human activity. Increased awareness and better safeguards are helping to reduce wildfire ignitions, but extreme conditions can still lead to significant fire events. Climate change is expected to expand fire-prone areas to the north and to the Mediterranean mountains, raising concerns about the management of these new high-risk zones [15], [16].

Land Use and Management

Inappropriate land use practices and inadequate land management contribute to the occurrence of wildland fire ignitions. The expansion of urban areas into wildland interfaces increases the likelihood of human-caused fires due to accidental ignitions or negligence. Additionally, the suppression of natural fire regimes disrupts ecosystems' natural processes, leading to an accumulation of fuel loads that can easily ignite.

Changes in land use, urban expansion, and the encroachment of human settlements into wildland areas can increase the likelihood of human-caused fires. Urbanization can bring more people into close proximity to fire-prone ecosystems, raising the risk of accidental ignitions.

Agricultural activities, such as slash-and-burn practices, can be a source of forest fire ignitions. Socioeconomic factors influencing these practices include agricultural policies, land tenure systems, and economic conditions affecting farming communities.

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Socioeconomic conditions affecting livelihoods and economic opportunities can influence behaviours that contribute to forest fire ignitions. For example, individuals may resort to activities like illegal logging or clearing land through fire for agriculture due to economic pressures.

Socioeconomic Factors

Population growth, socioeconomic disparities, and rural-urban migration contribute to increased human activities in fire-prone areas. Industrial activities, such as logging or mining, can also lead to accidental ignitions. Furthermore, socioeconomic factors affect the resources available for fire prevention and suppression efforts. Variables such as unemployment rates and agricultural activities can influence both intentional and unintentional fire ignitions [17].

Infrastructure Development:

Infrastructure development, including road construction and utility line installation, can introduce ignition sources and facilitate the spread of fires. Economic incentives driving infrastructure projects may influence the risk of forest fires in certain regions.

Poverty and Illegal Activities:

Higher poverty rates may lead to greater reliance on natural resources for sustenance, which may encourage illegal logging or poaching practices that raise the risk of forest fire ignitions.

Policy and Governance:

The effectiveness of policies and governance structures in regulating land use, firefighting resources, and fire prevention measures can be influenced by socioeconomic factors such as political stability, corruption levels, and the capacity of institutions.

Education and Awareness:

Socioeconomic factors affecting education levels and awareness in local communities can influence fire prevention practices. Lack of awareness or understanding of fire risks may contribute to accidental ignitions.

Population Dynamics:

Population growth and migration patterns can impact the distribution of human activities in wildland-urban interface areas, affecting the likelihood of fire ignitions. Rapid population growth may strain firefighting resources and increase the risk of accidental ignitions.

Cultural Practices and Traditions:

Cultural practices, traditions, and beliefs may influence activities that pose fire risks, such as the use of fire in land management practices. Integrating cultural perspectives into fire management strategies is important for their effectiveness.

Addressing forest fire ignitions requires a holistic approach that considers the interplay between human activities and socioeconomic factors. Effective strategies should involve collaboration among communities, policymakers, scientists, and other stakeholders to develop and implement measures that take into consideration these complexities.

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3.3.2 Challenges Associated with Wildland Fire Ignitions

Data Availability and Quality

Accurate and reliable data are essential for understanding the patterns and trends of wildland fire ignitions. However, challenges persist in data collection, standardization, and sharing. Incomplete or outdated data hinder the development of effective prevention strategies and limit the ability to assess the effectiveness of mitigation efforts. There is a lack of consistent and detailed records for wildland fire events within and across European countries [18].

Prevention and Mitigation Aspects

Preventing and mitigating wildland fire ignitions pose significant challenges. The vastness and remote nature of wildland areas make it difficult to implement preventive measures and respond rapidly to fire outbreaks. Limited resources, including funding and personnel, often constrain prevention and mitigation efforts. Additionally, public awareness and education regarding fire safety practices are crucial but can be challenging to achieve.

Interagency Coordination:

Wildland fire management involves multiple agencies and stakeholders, requiring effective coordination and collaboration. However, interagency coordination can be complex and hindered by bureaucratic processes, differing priorities, and conflicting regulations. Streamlining communication and decision-making processes is essential for enhancing the efficiency and effectiveness of fire management strategies.

Geographical Gradient:

There is a geographical gradient of fire ignition due to variations in climate, fuel composition, and population density [17]

Environmental Considerations

Wildland fire ignitions have profound environmental impacts. They can lead to habitat destruction, loss of biodiversity, and soil erosion. Moreover, the use of fire suppression strategies, such as aerial water drops or chemical retardants, can have unintended ecological consequences. Balancing fire management objectives with environmental considerations is a complex challenge that requires careful planning and assessment.
These factors highlight the complexity of managing wildland fires in Europe and underscore the need for comprehensive strategies that address both human and environmental aspects.

Fuel treatment near critical infrastructure

Implementing fuel treatment near critical infrastructure for the reduction of fire ignitions can present several challenges:

- Access and Safety: Ensuring safe access for crews to perform treatments near infrastructure like power lines or railways is crucial. There may be restrictions on how close machinery can operate to these structures.

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- Coordination with Infrastructure Operators: Collaborative planning with infrastructure operators is necessary to schedule treatments without disrupting services.
- Environmental Impact: Treatments must be conducted in a way that minimizes environmental damage, especially in sensitive habitats.
- Regulatory Compliance: Adhering to regulations that protect the environment and public safety while conducting treatments can be complex.
- Public and Stakeholder Engagement: Gaining support from the public and stakeholders for treatment plans is essential for successful implementation.
- Funding and Resources: Securing adequate funding and resources for comprehensive treatment programs can be challenging.
- Technological Integration: Utilizing advanced technologies such as remote sensing for risk mapping requires expertise and can be cost-intensive.
- Maintenance: Ongoing maintenance of treated areas is necessary to ensure long-term effectiveness, which requires continuous funding and labour.

These challenges require careful planning, coordination, and resource allocation to ensure that fuel treatments are effective and do not adversely affect critical infrastructure or the surrounding environment.

3.4 Policies, best practices and lessons learned

Forest fire prevention policies in the European Union (EU) aim to mitigate the risks associated with wildfires and protect valuable forest ecosystems. Key aspects of forest fire prevention policies in the EU include the following:

1. Early detection and monitoring: Implementing systems for early detection and monitoring of forest fires is crucial. This involves the use of advanced technologies such as satellite imagery, drones, and weather monitoring systems to identify and track potential fire incidents.

2. Fire risk assessment and mapping: Conducting fire risk assessments and mapping helps identify areas prone to wildfires. This information is used to prioritize prevention measures and allocate resources effectively.

3. Firebreaks and fuel management: Creating firebreaks, which are cleared areas that act as barriers to slow down or stop the spread of fires, is an important preventive measure. Additionally, managing fuel loads through controlled burns, vegetation management, and forest thinning helps reduce the intensity and spread of wildfires.

4. Public awareness and education: Raising public awareness about the risks of forest fires and promoting responsible behaviour in forested areas is crucial. This includes educating the public about fire safety, proper disposal of cigarette butts, and the importance of reporting potential fire hazards.

5. Collaboration and coordination: Forest fire prevention policies emphasize collaboration among various stakeholders, including forest owners, fire services, local communities, and regional authorities. Cooperation and coordination help ensure effective response and prevention strategies.

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6. Firefighting capabilities: Maintaining well-equipped and trained firefighting teams, including aerial firefighting resources, is essential for rapid response and containment of forest fires. This includes investing in firefighting equipment, training programs, and interagency cooperation.

7. Research and innovation: Continuous research and innovation play a vital role in improving forest fire prevention policies. This involves studying fire behaviour, developing new technologies for early detection and monitoring, and exploring sustainable forest management practices.

It is important to note that forest fire prevention policies vary across EU member states due to differences in climate, vegetation, and forest management practices.

Forest fires pose a significant threat to the environment, economy, and human lives across the European Union (EU). As climate change intensifies, the risk of forest fires becomes even more pronounced. In order to mitigate this risk, it is crucial to implement best practices and learn from past experiences. Forest fire prevention requires a multi-faceted approach that combines early detection, community involvement, proactive forest management, and effective policies.

The EU has made significant strides in implementing best practices and policies to mitigate the impact of forest fires. By learning from past experiences and continuously improving strategies, the EU can better protect its forests and communities from this devastating threat.

3.4.1 Lessons Learned

- Early Detection and Rapid Response

Timely detection of forest fires is essential for effective containment. Employing advanced technologies such as satellites, drones, and surveillance systems enables quick identification of fire outbreaks. Once detected, a rapid response with well-trained fire brigades can help minimize the spread and impact of fires.

- Community Involvement

Engaging local communities is vital for successful forest fire prevention. Educating residents about fire risks, establishing community-based warning systems, and encouraging responsible behaviour can significantly reduce the occurrence of fires caused by human activities.

- Proactive Forest Management

Implementing proactive forest management practices, such as controlled burns and vegetation clearing, helps reduce fuel loads and limit the severity of potential fires. Regular monitoring of forests and maintaining firebreaks can aid in early detection and control.

3.4.2 Policies in the EU

The EU has recognized the importance of preventing forest fires and has implemented various policies to address this issue. Some key policies include:

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- **European Forest Fire Information System (EFFIS):** EFFIS [19] serves as a centralized platform for collecting and disseminating information related to forest fires. It provides real-time data on fire risk, burnt areas, and weather conditions, aiding in effective fire management.

- **Integrated Fire Management (IFM)**: IFM focuses on a holistic approach to fire prevention, combining preventive measures, early detection, and efficient response strategies. This approach ensures coordination among different stakeholders involved in fire management.

- **Funding and Support:** The EU provides financial support to member states for forest fire prevention and mitigation efforts. This funding helps improve infrastructure, invest in advanced technologies, and enhance the capacity of fire brigades.

3.4.3 Best Practices

- Public Awareness Campaigns

Conducting public awareness campaigns to educate citizens about the risks and consequences of forest fires can foster responsible behaviour and reduce human-caused fires. These campaigns should emphasize the importance of fire safety measures and the need to report any potential fire hazards.

- Collaboration and Cooperation

Promoting collaboration among member states, sharing best practices, and exchanging resources can enhance the collective response to forest fires. Cooperation at regional and international levels strengthens the effectiveness of prevention strategies.

- Investment in Technology

Embracing technological innovations, such as early warning systems, remote sensing, and artificial intelligence, can improve the accuracy and efficiency of forest fire prevention. Investing in research and development of advanced technologies is a priority.

4 Guidelines

4.1 State of the art

4.1.1 Existing guidelines

Wildfires pose significant threats to communities, ecosystems, and economies worldwide. As these infernos become increasingly frequent and intense, proactive measures are imperative to mitigate their devastating impact. In response, guidelines for wildfire prevention have been developed, drawing upon best practices, scientific research, and community engagement. These guidelines serve as a roadmap for individuals, communities, and policymakers alike, offering actionable steps to reduce the risk of wildfires and safeguard lives and livelihoods. From landscape management strategies to community preparedness initiatives, these guidelines encapsulate the collective wisdom and expertise necessary to confront this pressing challenge. By adhering to these principles, stakeholders can play a

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proactive role in protecting against the ravages of wildfire, fostering resilience in the face of an ever-changing environment.
A set of guidelines for wildfire prevention is listed below, drawing upon best practices, scientific research, and community engagement.

• **Wildfire Prevention | European Forest Institute:** A webpage that provides information and recommendations on how to prevent wildfires in the Mediterranean region, where wildfires are a recurrent and increasing problem. The webpage highlights the importance of involving local communities in prevention efforts and showcases five best-practice cases from Catalonia, Lebanon, Portugal, Greece, and Andalusia. The webpage also links to relevant EU policies and initiatives, such as the EU Forest Strategy, the EU Civil Protection Mechanism, and the EU Green Deal
https://efi.int/wildfire-prevention

• **Land-based wildfire prevention** - Publications Office of the EU: A booklet that summarizes the current and future trends of wildfires in Europe and the tools to monitor them at the European and country levels. The booklet also provides an overview of existing land-based wildfire prevention and good practices, such as fuel management, prescribed burning, landscape planning, and fire-smart agriculture. The booklet is based on the work of the Expert Group on Forest Fires, which is a consultative body initiated by the European Commission to provide advice on wildfire management
https://op.europa.eu/en/publication-detail/-/publication/4e6cc1f1-8b8a-11eb-b85c-01aa75ed71a1

• **WILDFIRE AND WILDERNESS:** A factsheet that outlines the legal and policy framework for managing wildfires in wilderness areas in the United States. The factsheet explains the difference between natural and human-caused wildfires, and the role of fire in maintaining natural processes and biodiversity. The factsheet also describes the principles and practices of fire management in wilderness, such as fire suppression, prescribed fire, and fire use. The factsheet is based on the Wilderness Act of 1964, the Federal Wildland Fire Management Policy, and the Forest Service regulations
https://www.wilderness.org/sites/default/files/media/file/Factsheet-Wilderness%20and%20Wildfire-A%20Brief%20Primer.pdf.

• **Guidelines for Fire Suppression Systems and Fire Fighting Hand Tools - BC Forest Safe**: A guideline that provides information and recommendations on how to install and maintain fire suppression systems and fire fighting equipment on logging equipment and vehicles in British Columbia, Canada. The guideline aims to reduce the risk of fire ignition and spread from logging operations, which are a common cause of wildfires in the province. The guideline is based on the Wildfire Act and Regulation, the Occupational Health and Safety Regulation, and the Workers Compensation Act
https://www.bcforestsafe.org/node/1312.

• **Wildfire Mitigation Reference Guide:** A reference guide that provides information and recommendations on how to mitigate the risk of wildfires caused by or affecting electric transmission and distribution systems in North America. The guide covers topics such as vegetation management, system design and operation, fire detection and response, and stakeholder coordination. The guide is based on the best practices and lessons learned from various utilities, agencies, and organizations

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https://nerc.com/comm/RSTC/Documents/Wildfire%20Mitigation%20Reference%20Guide_January_2021.pdf.

4.1.2 Guidelines for Acceptable Safety Distances (ASDs) Near Critical Infrastructure

Romero-Ruiz et. al., 2016 [20] presented a probabilistic model to reduce the probability of line congestions and voltage violations in a smart grid located in a radial distribution network. Abrar et al., 2018 [21] proposed a metering network that collects the real-time load data for smart grid and monitors the theft detection, line losses in distribution network and optimized scheduling of renewable energy resources. Dian et. al., 2019 [22] designed an integrated wildfire early warning system framework for power grids, taking prediction of wildfires and early warning of line outage probability together. In the scenario, new installations of reversible substations in DC railway systems, can improve energy savings. In order to evaluate the impact of this innovative technology, a preliminary analysis of the data acquired during a measurement campaign conducted jointly with Metro de Madrid (train and substation owner) and Hitachi Rail (train manufacturer) is presented [23]. Since a shared electric grid is suffering from power superimposition, when several trams charge at the same time, Wei et. al., 2020 [24] proposed to install stationary energy storage systems (SESSs) for power supply network to downsize charging equipment and reduce operational cost of the electric grid. A risk analysis method to probabilistically analyze the tripping accidents of power transmission lines caused by wildfire, lightning, strong wind and ice storm was proposed [25]. Kody et. al.(2022) [26] proposed a multi-period optimization formulation that locates and sizes infrastructure investments while simultaneously choosing line de-energizations to minimize wildfire ignition risk and load shedding. In an effort to prevent and minimize the ignition of wildfires, or control them if ignited, energy companies have developed wildfire mitigation plans. Vazquez et. al., 2022 [27] provide energy companies and power system operators, engineers, researchers, and suppliers an overview of the state-of-the-art studies that address key topics in these wildfire mitigation plans and compares the wildfire mitigation plans of several energy companies. Previous works have not explicitly considered the impacts of such outages. To address this gap Rhodes et. al.,2023 [28] proposed the Security-Constrained Optimal Power Shutoff (SC-OPS) problem, which uses post-contingency security constraints to model the impact of unexpected line faults when planning a PSPS.

Ali Arab et al.,2021 [29] proposed a tripartite framework for managing wildfire risks in electric power infrastructure, termed "3LD," which focuses on wildfire prevention as the first line of defense, mitigation, and proactive response as the second, and recovery preparedness as the third. The paper highlights the need for a holistic, interdisciplinary approach to address gaps in current research on power system resilience and wildfire risk management.

These papers collectively provide insights into wildfire utility ignitions and vegetation management. Muhs 2020 [30] discusses the challenges and strategies for wildfire risk mitigation in power systems, including vegetation management and ignition prevention methods. Vazquez, 2022 [27] reviewed the wildfire mitigation plans of energy companies, highlighting topics such as grid design, asset management, and vegetation management. Molina, 2019 [31] highlighted the significance of assessing fire ignition potential in roadside vegetation, with distance to roads and settlements being key variables. Stidger, 2004 [32] emphasised the role of vegetation management programs, including prescribed burns, in controlling wildfires.

Stagl 2013 [33] focused on the importance of vegetation control along train tracks to prevent visibility issues, communication interference, and fire hazards. Molina, 2019 [31] highlighted the significance of assessing fire ignition potential in roadside vegetation, with distance to roads and settlements being key variables. Kuklina, 2022 [34] examined the associations between road networks and wildfire events, finding a spatial relationship between wildfire

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ignition points and different types of roads. Curt, 2010 [35] discussed the optimization of fuel treatment and landscape patterning in road-forest interfaces to reduce fire hazard [36].

4.2 Guidelines related to legal aspects and Policy

4.2.1 Power network

Reducing power line ignitions is crucial in preventing devastating forest fires. Power line operators, authorities, and communities can work together to minimize the risk of wildfires significantly. Regular inspections, thorough maintenance, installation of protective measures, public awareness, and collaboration with local authorities are key steps towards ensuring power line safety and protecting our environment.

Utility Liability and Accountability

Establish clear guidelines regarding utility liability for wildfire incidents caused by their equipment. This includes defining responsibilities, compensation mechanisms, and accountability measures.
Develop policies that encourage utilities to invest in fire prevention and mitigation strategies to minimize their impact on wildfire ignition.

Regulatory Oversight

Regulatory bodies should closely monitor utilities' compliance with safety standards and wildfire prevention protocols. Implement inspections to ensure adherence to guidelines related to vegetation management, equipment maintenance, and fire-resistant infrastructure.

Utilities' Emergency Response Plans

Utilities must have robust emergency response plans in place. These plans should outline actions to be taken during wildfire events, including communication protocols, coordination with firefighting agencies, and public safety measures.
Legal requirements should mandate the development and periodic testing of these plans.

Encourage Coordination with Local Authorities

Policies should encourage collaboration between utilities and local fire departments, emergency services, and forest management agencies.
Establish mechanisms for sharing information, coordinating efforts, and responding swiftly to wildfire threats.

Government Mitigation Funding and Incentives

Governments can provide financial incentives for utilities to invest in wildfire prevention measures. These incentives may include tax breaks, grants, or low-interest loans.
Allocate funds specifically for wildfire risk reduction and infrastructure upgrades.

Legal Frameworks for Public Awareness and Education

Legal frameworks should promote public awareness campaigns about wildfire risks near power lines.

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Legislation on Equipment Standards

Enact laws that mandate the use of fire-resistant materials in power infrastructure construction.
Set minimum safety standards for equipment design, installation, and maintenance.

Climate Adaptation Policies for power network planning

Develop policies that integrate climate adaptation strategies into power network planning and operations.

4.2.2 Road network

Follow local regulations and restrictions: Familiarize yourself with the rules and regulations regarding fire safety in the area where you are driving. Pay attention to any fire restrictions or bans that may be in place.

Maintain vehicle properly

Proper vehicle maintenance, particularly regarding the exhaust system, plays a critical role in wildfire prevention. A malfunctioning exhaust system can release sparks or hot materials capable of igniting dry vegetation, especially in forest areas. The emphasis on vehicle maintenance as a wildfire preventive measure is supported by several studies:
Exhaust System Maintenance: Regular checks and repairs to the vehicle's exhaust system are crucial. A damaged or poorly maintained exhaust can emit hot gases or particles that can ignite dry vegetation, especially in areas adjacent to road networks . Additionally, the installation of spark arrestors on vehicles frequently used in fire-prone areas can significantly reduce the risk of wildfires.
Catalytic Converter Safety: The catalytic converter, a part of the vehicle's exhaust system, can reach very high temperatures. Ensuring it functions correctly and is free from damage is vital to preventing the ignition of flammable materials. Vehicles should be parked in designated areas, away from dry vegetation, to avoid heat transfer from the catalytic converter to potential fuels.
Fuel System Integrity: Ensuring the fuel system is leak-free is important. Leaks can lead to flammable liquids coming into contact with hot surfaces of the vehicle, increasing the risk of fires.
Engine Maintenance: Regular engine maintenance is essential. Overheating engines can be a source of ignition. Ensuring the cooling system is functioning correctly helps in reducing the risk of engine fires that can spread to the surroundings.
Educational Campaigns and Training: Providing education and training to drivers and vehicle owners about the importance of vehicle maintenance in preventing wildfires is crucial. Awareness campaigns can be conducted, especially in regions prone to forest fires.
Regulatory Compliance and Inspections: Ensuring vehicles meet safety standards through regular inspections can help identify and rectify potential fire hazards. Authorities can implement stringent regulations for vehicle maintenance, especially for those operating near forest areas.

Avoid parking on dry vegetation:

To effectively prevent wildfires, especially in forested areas, it is crucial to avoid parking vehicles on dry vegetation. Vehicles, particularly their undercarriages and exhaust systems, can reach high temperatures that are capable of

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igniting dry grass, leaves, or underbrush. This can be a significant source of wildfires, especially during periods of dry weather. Enhancing this understanding with scientific research, we conclude the following:

Risk from Vehicles: Vehicles are identified as a potential source of wildfire ignitions, especially when parked over dry vegetation. The heat from the undercarriage or exhaust systems can be enough to start a fire under suitable conditions, as noted in studies that emphasize the role of human activities in wildfire ignition [37].

Management of Roadside Vegetation: The planning and conservation of roadside vegetation are important for wildfire prevention. Research indicates that evaluating the flammability of vegetation species found on roadsides can significantly aid in mitigating wildfire risks. The composition and management of roadside vegetation can reduce the likelihood of ignition [31].

Public Awareness and Regulation: Increasing public awareness about the dangers of parking on dry vegetation is essential. Additionally, implementing and enforcing regulations that restrict parking in high-risk areas during wildfire season can significantly reduce the risk of fire ignitions.

Designated Parking Areas: Encouraging the use of designated parking areas, especially in fire-prone regions, can help prevent vehicle-related wildfire ignitions. These areas should be carefully selected and maintained to minimize the presence of flammable materials.

Monitoring and Enforcement: Active monitoring of parking behaviors, especially in high-risk areas during peak wildfire seasons, coupled with strict enforcement of parking regulations, can effectively reduce the risk of wildfires.

Be cautious with towing equipment:

Being cautious with towing equipment is a critical aspect of wildfire prevention, especially in areas prone to such incidents. Equipment such as safety chains, tow bars, and other metal parts, if not properly secured, can drag on the ground and create sparks that may ignite dry vegetation. Enhancing this understanding with recent scientific research, we conclude the following:

Risk from Dragging Towing Equipment: Dragging metal parts from towing equipment, such as chains or tow bars, pose a significant risk of igniting wildfires, especially when they come into contact with dry vegetation or rough surfaces. This risk is particularly high during dry conditions, as these sparks can easily ignite dry grass and brush [38].

Education and Training for Towing Safety: Providing education and training to drivers on proper towing practices is essential. Drivers should be trained on securing all towing equipment correctly to prevent any part from dragging on the ground and generating sparks.

Regular Inspections and Maintenance of Towing Equipment: Regular safety checks and maintenance of towing equipment should be mandatory, especially for vehicles operating in fire-prone areas. This includes ensuring that safety chains and tow bars are not only secure but also in good condition.

Regulatory Compliance and Best Practices: Implementing and enforcing regulations that ensure proper use and maintenance of towing equipment can greatly reduce the risk of wildfires. These regulations may include mandatory inspections of towing equipment for vehicles entering high-risk areas.

Innovative Solutions and Technologies: Research and development of new technologies that reduce the risk of ignition from towing equipment can also contribute to wildfire prevention. This may include innovations in the design of towing equipment that minimize the risk of dragging and sparking.

Community Engagement and Awareness Campaigns: Engaging communities in awareness campaigns about the risks associated with improper towing practices and the potential to cause wildfires is important. Such campaigns can include signage in high-risk areas and educational materials distributed to vehicle owners and operators.

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A guideline for **Mitigating Wildfire Risks with Towing Equipment** should consider the **Development and Implementation of a Standardized Towing Safety Protocol**. This protocol should outline the necessary steps and checks that drivers must perform before and during towing in high-risk areas. This includes:

- A checklist for inspecting towing equipment before use, ensuring everything is properly secured and in good condition.
- Clear guidelines on the correct use of safety chains, tow bars, and other equipment to prevent dragging and sparking.
- Mandatory training for drivers on towing safety, focusing on the risks of wildfire ignition.
- Enforcement measures to ensure compliance with these safety protocols, including potential fines or penalties for non-compliance.
- Incorporation of advanced technology or design modifications in towing equipment to minimize the risk of sparking.
- Collaboration with local authorities and communities to raise awareness and ensure widespread adoption of these safety practices.

Avoid off-road driving

Avoiding off-road driving is an essential strategy for preventing wildfires, particularly in forested and rural areas. Off-road driving can disturb the natural terrain, exposing more flammable materials and potentially causing sparks that ignite wildfires. This concern is backed by recent scientific research, emphasizing the significance of controlling off-road vehicle activities to reduce wildfire risks, as follows:

Risk of Wildfire Ignition from Off-Road Driving: Vehicles travelling off established roads can inadvertently ignite wildfires. The combination of hot undercarriages, exhaust systems, and the friction caused by tyres or metal parts against dry vegetation or rocky terrain increases the risk of sparks and fire ignitions. Research on fire prevention emphasizes the need for awareness and regulation of vehicle movements in fire-prone landscapes to mitigate this risk [39].

Impact of Road Networks on Wildfire Distribution: Studies have shown that the spatial distribution of wildfires is significantly influenced by the density and layout of road networks. Roads can act as both a barrier to and an ignition source for wildfires. Managing off-road driving, particularly in areas with high wildfire risk, is crucial to reducing fire occurrences [40].

Enforcement of Off-Road Driving Restrictions: Strict enforcement of regulations prohibiting off-road driving in high-risk areas is necessary. This includes implementing fines and penalties, as well as educational campaigns to inform the public about the risks associated with off-road driving.

Monitoring and Surveillance of High-Risk Areas: Using advanced monitoring techniques, such as aerial surveillance and sensors, to detect unauthorized off-road vehicle activity can be effective in preventing wildfire ignitions.

Promoting Responsible Recreation: Encouraging responsible recreational activities that do not involve off-road driving can help reduce the risk of wildfires. Providing designated areas for such activities, away from high-risk zones, is an effective strategy.

Guidelines for policies and legislation for reducing wildfire risks associated with off-road driving may include:

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Establishment of Clear Off-Road Driving Regulations: Define and enforce strict regulations prohibiting off-road driving in areas identified as high-risk for wildfires. These regulations should be clearly communicated to the public and visitors to these areas.

Development of Monitoring and Enforcement Strategies: Utilize advanced monitoring techniques such as drone surveillance, sensor networks, and regular patrols to detect and deter unauthorized off-road vehicle activity in high-risk zones. Ensure that there are effective enforcement mechanisms in place, including fines and legal penalties for violations.

Public Education and Awareness Campaigns: Conduct educational campaigns targeting both local residents and visitors to raise awareness about the dangers of off-road driving in fire-prone areas. Use various communication channels, including social media, local media, signage in key locations, and community outreach programs.

Promotion of Responsible Recreational Practices: Encourage recreational activities that do not involve off-road driving, especially in sensitive ecological areas. Provide information on alternative activities and designated areas for recreational use that pose a lower risk of wildfire ignition.

Collaboration with Local Communities and Stakeholders: Work closely with local communities, recreational groups, environmental organizations, and other stakeholders to promote understanding and compliance with off-road driving regulations. Encourage community involvement in monitoring and reporting unauthorized activities.

Report any signs of fire

Reporting signs of fire promptly and accurately is a crucial step in wildfire prevention and control, especially in forested and rural areas. Timely reporting can significantly reduce the spread of wildfires, thereby minimizing environmental, economic, and human losses. Research underscores the importance of public awareness and the effective use of technology in early fire detection and reporting as follows:

Importance of Public Reporting: The public plays a vital role in early wildfire detection. Educating communities on identifying and reporting signs of fire can lead to quicker response times. Awareness programs should focus on how to accurately describe the location, size, and behavior of the fire to authorities [41].

Advancements in Reporting Technologies: Emerging technologies, including mobile applications and social media platforms, provide new avenues for the public to report wildfires. Utilizing these platforms can expedite the sharing of information with emergency services and wildfire management teams [42].

The proposed Policy Guidelines for Enhancing Wildfire Reporting are as follows:

Establish a Comprehensive Public Reporting System: Develop a user-friendly public reporting system for wildfires, utilizing modern communication technologies. This system could include a dedicated hotline, mobile app, or a web portal specifically designed for reporting wildfires. The system should be capable of quickly transmitting reports to local fire departments and forest management authorities.

Conduct Public Education Campaigns: Regularly conduct educational campaigns to inform the public about the importance of reporting wildfires. Provide guidelines on what information to include in a report, such as the location, size, and any observed behavior of the fire.

Integration with Local Emergency Services: Ensure that the reporting system is well-integrated with local emergency services to enable swift action. Establish protocols for verifying reports and deploying resources based on the information received.

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Encourage Community Involvement: Foster a sense of community responsibility for wildfire prevention. Engage local organizations, schools, and community groups in spreading awareness about the importance of reporting wildfires.

Fire restrictions and bans

Implementing fire restrictions and bans during periods of high fire danger is a critical measure in wildfire prevention, particularly in forested and rural areas. These restrictions can include limitations on open fires, campfires, or the use of certain equipment that could potentially cause sparks or ignite fires. Recent studies emphasize the importance and effectiveness of such measures:

Effectiveness of Fire Restrictions and Bans: Research suggests that there have been significant advances in developing models and approaches to estimating the likelihood of wildfire occurrences. Fire restrictions and bans, as part of a broader wildfire prevention strategy, can reduce both the likelihood of and damage from unwanted wildfires [43].

Community Awareness and Compliance: Ensuring community awareness and compliance with fire restrictions is vital for their effectiveness. Educational campaigns and clear communication are crucial in informing the public about the reasons for restrictions and the penalties for non-compliance.

Policy guidelines for implementing fire restrictions and bans may consider activities as follows:

Development of a Comprehensive Fire Restriction Framework: Establish a clear and comprehensive framework for implementing fire restrictions and bans. This framework should be based on scientific data, weather conditions, and the assessment of fire risk in different areas.

Effective Communication Strategies: Use various channels, including social media, local news, and community meetings, to communicate fire restrictions and bans to the public. Ensure that the reasons behind these measures are clearly explained, along with the potential consequences of non-compliance.

Enforcement and Monitoring: Collaborate with local law enforcement and fire management authorities to ensure the enforcement of fire restrictions. Conduct regular patrols in high-risk areas and establish penalties for violations.

Community Engagement: Involve local communities in the decision-making process regarding fire restrictions. Seek feedback and suggestions from residents and stakeholders to enhance the effectiveness and acceptance of these measures.

Regular Review and Adjustment: Regularly review the effectiveness of fire restrictions and make adjustments based on changing conditions and feedback. This includes being flexible in lifting bans when conditions improve to maintain public trust and cooperation.

Roadside parking regulations

Enforcing roadside parking regulations is a key strategy for wildfire prevention, particularly in areas with high wildfire risks. These regulations typically prohibit parking in areas with dry vegetation or require vehicles to be parked in designated areas. The effectiveness of such measures in reducing wildfire risks is supported by recent research:

Management of Fire-Prevention Distances: The analysis of regulatory requirements for fire safety, specifically concerning the spread of fire from vehicle parking lots to various buildings and structures, highlights the importance of establishing fire-prevention distances. This approach involves assessing the ignition potential of irradiated materials from radiant heat flux during a fire, which is essential for setting safe distances between parked vehicles and surrounding flammable materials [44].

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Roadside Vegetation Planning: The planning and conservation of roadside vegetation can play a crucial role in fire prevention. Research focusing on the fire ignition potential of roadside vegetation identifies the importance of distance to roads and settlements as key variables explaining fire ignition potential. Managing the type and flammability of roadside vegetation based on these factors can significantly aid in mitigating wildfire risks [31].

Policy guidelines for implementing regulations on roadside parking may include activities as follows:

Development of Specific Roadside Parking Regulations: Establish clear and enforceable regulations for roadside parking, particularly in wildfire-prone areas. These regulations should identify high-risk zones where parking is restricted, especially during periods of elevated fire risk.

Public Education and Signage: Implement a public education campaign to inform drivers about the risks associated with roadside parking in dry vegetation areas. Utilize clear and visible signage to indicate no-parking zones and designated safe parking areas.

Monitoring and Enforcement: Collaborate with local law enforcement and fire management authorities to monitor compliance with roadside parking regulations. Regular patrols and surveillance in high-risk areas should be conducted, and penalties enforced for violations.

Strategic Designation of Safe Parking Areas: Identify and develop designated parking areas that are strategically located away from high-risk zones. These areas should be well-maintained to minimize the presence of flammable materials and should be clearly marked for public use.

Regular Review and Adjustment of Regulations: Continuously evaluate the effectiveness of the roadside parking regulations and make necessary adjustments based on changing conditions, feedback, and new research findings.

Off-road driving restrictions

Implementing restrictions on off-road driving is a key component in preventing wildfires, especially in areas with high fire risk such as forests and grasslands. Off-road driving can significantly disturb the environment, leading to an increased likelihood of wildfire ignitions. Research supports the effectiveness of the influence of road networks on wildfire spread. Studies indicate that road networks can have a considerable impact on the spatial distribution of wildfires. The presence of roads can either act as barriers or ignition sources for wildfires, suggesting that managing off-road driving, particularly in fire-prone areas, is crucial for wildfire prevention [40].

Proposed guidelines for implementing off-road driving restrictions may include activities as follows:

Establishment of Clear Off-Road Driving Policies: Develop and enforce comprehensive policies that restrict off-road driving in high-risk wildfire areas. These policies should be based on scientific evidence and consider factors such as the local environment, fire history, and current weather conditions.

Effective Communication and Signage: Utilize various communication methods, including signage at key entry points, to inform the public about off-road driving restrictions. Ensure that the reasons and potential risks associated with off-road driving are clearly communicated.

Monitoring and Enforcement Measures: Implement monitoring systems, possibly including aerial surveillance and on-the-ground patrols, to ensure compliance with off-road driving restrictions. Enforce penalties for violations to deter unauthorized activities.

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Public Education and Outreach: Conduct public education campaigns to raise awareness about the risks of off-road driving, specifically wildfire ignition. Collaborate with local community groups, recreational organizations, and educational institutions to disseminate this information.
Regular Assessment and Adaptation of Policies: Continuously evaluate the effectiveness of the off-road driving restrictions and adapt policies as necessary. This could involve adjusting restricted areas based on changing environmental conditions or new research findings.

Proper disposal of smoking materials

One of the most common human causes of wildfires, especially in areas adjacent to road networks, is the improper disposal of lit cigarettes. To address this, legal and regulatory measures may be considered.
Strict Enforcement of Fines and Penalties: Implement and rigorously enforce fines and penalties for throwing lit cigarettes from vehicles. This serves as a deterrent and raises public awareness about the seriousness of this action.
Public Education Campaigns: Conduct targeted educational campaigns to inform the public about the risks associated with discarding lit cigarettes from vehicles. These campaigns can include information on how such behaviour contributes to the ignition of wildfires and the potential consequences.
Reporting Mechanisms: Encourage the public to report incidents of lit cigarettes being discarded from vehicles. Provide easy and anonymous ways to report such behaviour, and ensure that there are follow-ups on these reports.
Vehicle Ashtray Use Encouragement: Promote the use of vehicle ashtrays and provide them at public locations such as gas stations, rest areas, and parks. This encourages smokers to extinguish cigarettes inside their vehicles safely.
Signage and Messaging: Use highway and roadside signage to remind drivers of the dangers and legal repercussions of throwing cigarettes out of their vehicles. Include messages on electronic road signs, especially during periods of high fire risk.

Reporting requirements

Effective reporting of wildfires by drivers and other citizens using or operating along road networks is crucial for rapid response and management of wildfires. Prompt and accurate reporting from road network users can play a pivotal role in the early detection and control of wildfires, especially in areas adjacent to roads and highways. Adapting the context of wildfire reporting to this specific group involves policies and legislation as defined here next:
Targeted Education and Awareness for Road Users: Educate drivers and road users about the importance of reporting signs of fire. Provide guidelines on how to identify and report fires, emphasizing the need for details like the exact location (possibly using GPS coordinates), the size, and visible characteristics of the fire.
Integration with Traffic and Emergency Services: Link reporting mechanisms with traffic management and emergency response systems. This integration can facilitate swift communication and coordination between road users, fire management authorities, and emergency services.
Use of Technology for Efficient Reporting: Encourage the use of mobile applications and in-vehicle systems for reporting wildfires. These technologies can provide a quick and easy way for drivers to report fires, with features like one-click reporting or automatic location sharing.

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Clear Signage Along Road Networks: Install clear signage along roads, especially in high-risk areas, to remind drivers of the importance of reporting wildfires and providing guidance on how to do so. This can include information on emergency contact numbers or instructions for using reporting apps.

Regular Drills and Simulations: Conduct regular drills and simulations involving road users to practice wildfire reporting procedures. This can help in familiarizing them with the reporting process and reinforcing the importance of their role in wildfire management.

Feedback and Incentive Mechanisms: Implement feedback mechanisms to acknowledge and, where appropriate, reward road users for their vigilance and reporting. This can encourage a culture of proactive reporting and community involvement in wildfire management.

4.2.3 Rail network

Research in the domain of railway network-related wildfire ignitions provides critical insights into state-of-the-art practices and recommendations. Key among these is the need for fire prevention and management tailored to the railway environment. This involves developing policies that effectively balance suppression strategies with preventive measures, focusing on ignition causes specific to railway activities such as sparks from braking systems or electrical faults. Studies emphasize the importance of understanding the unique fire risks associated with railway operations to formulate targeted policies and legislation [45]. Equally vital is the integration of wildfire risk assessments into railway safety protocols. This includes implementing regular inspections of railway infrastructure, conducting fire safety training for railway staff, and developing specialized emergency response plans that address potential wildfire incidents near railway lines.

Proposed guidelines for railway network-related wildfire policy and legislation may consider:

Development of Railway-Specific Wildfire Prevention Policies: Create policies that address the unique aspects of wildfire risks associated with railways. This includes regulations on maintenance practices, materials used in railway construction, and operating procedures that minimize the risk of ignitions.

Regular Infrastructure Inspections and Maintenance: Implement mandatory regular inspections and maintenance of railway infrastructure to identify and rectify potential hazards that could lead to wildfires.

Training and Awareness Programs for Railway Staff: Conduct regular training and awareness programs for railway staff to identify and manage fire risks effectively. This should include procedures for reporting potential hazards and responding to fire incidents.

Integration with Local Fire Management Authorities: Collaborate with local fire management authorities to develop joint response strategies for wildfires near railway lines. This might include sharing of resources and information, joint training exercises, and coordinated response plans.

Research and Development of Fire-Resistant Materials and Technologies: Promote research into fire-resistant materials and technologies for railway construction and maintenance. This includes developing and implementing new technologies that reduce the risk of sparks or other ignition sources.

Public Awareness Campaigns: Conduct public awareness campaigns to educate communities near railway lines about the risks of wildfires and the importance of reporting any signs of fire immediately.

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4.3 Technical Guidelines

4.3.1 Critical infrastructure

Optimizing vegetation management in the vicinity of critical infrastructure—namely, electrical grids, vehicular roadways, and rail transport systems—is imperative for the mitigation of wildfire ignition and propagation risks.
The determination of AccepTable Safety Distances (ASDs) for vegetation clearance is a multifactorial problem, influenced by variables such as vegetation morphological characteristics, local climatological conditions, and engineering specifications of the infrastructure in question. The following heuristic guidelines synthesize extant scientific and expert knowledge, and industry best practices, and align with regulatory stipulations to provide a comprehensive framework for risk-based vegetation management.

Thorough Maintenance

Regular maintenance of power lines through tree trimming and vegetation management is crucial. This practice prevents contact between power lines and flammable materials, thus reducing the likelihood of ignitions. The use of viscoelastic retardant fluids on high-risk landscapes has shown promise in preventing ignitions at the source, which is particularly relevant for areas near utilities infrastructure [37].

Regular Inspections

Frequent inspections of power lines are necessary to identify potential hazards or damage. This proactive approach ensures that risks are mitigated promptly. The application of advanced technologies, like Pin&Post, an app-based reporting system, can assist in crowdsourcing data on wildfire hazards like excess vegetation around power lines, enhancing the effectiveness of these inspections [46].

Installation of Protective Measures

In high-risk areas, installing fire-resistant covers or insulators on power lines can prevent sparks or electrical arcs from causing wildfires. Also, integrating fault detection systems and automatic circuit reclosers can address power line faults that could lead to fires.

Base ASD Guidelines

Establishing minimum clearances based on the voltage of power lines and the type of roads and railways is essential. These distances vary depending on the infrastructure type and are influenced by local climatic conditions and vegetation types. For example, in dry climates, it is advisable to increase the base ASD values by a certain multiplier to account for the increased fire risk.

Base ASD Guidelines for Power Grids

Infrastructure Type	Base ASD	Notes
High-Voltage Transmission Lines	30 meters	On either side of the centerline
Medium-Voltage Distribution Lines	15 meters	On either side
Low-Voltage Lines	5 meters	On either side

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In managing wildfire risks around power grids, it's crucial to establish Base Acceptable Safety Distances (ASDs) that vary depending on the type of power lines. For high-voltage transmission lines, a minimum clearance of 30 meters is recommended on either side of the centerline. This distance ensures a safety buffer between the power lines and any potential flammable vegetation or structures. For medium-voltage distribution lines, a slightly smaller safety margin is required, with a recommended distance of 15 meters on either side of the lines. This space is considered sufficient to reduce the risk of fire ignitions due to its proximity to vegetation. Lastly, for low-voltage lines, a minimum clearance of 5 meters on either side is advised. These varied distances take into account the differing intensities and potential risks associated with each voltage level, ensuring that safety measures are appropriately calibrated to the specific characteristics of each type of power line infrastructure.

Base ASD Guidelines for Road Networks

Infrastructure Type	Base ASD	Notes
Highways	10 meters	From the edge of the road
Secondary Roads	5 meters	From the edge

For road networks, implementing Base Acceptable Safety Distances (ASDs) is essential to mitigating wildfire risks. For highways, a minimum clearance of 10 meters from the edge of the road is recommended. This distance serves as a safety buffer to reduce the likelihood of wildfires being ignited by vehicles or other road-related activities and spreading to adjacent areas. Secondary roads, which generally experience less traffic and lower speeds compared to highways, have a recommended safety margin of 5 meters from the edge. This distance is deemed sufficient to prevent the ignition of nearby flammable vegetation by sources typically associated with roadways. These ASD guidelines for road networks are designed to balance safety requirements with practical considerations, aiming to reduce wildfire risks while maintaining the efficiency and functionality of the road infrastructure.

Base ASD Guidelines for Railways

Infrastructure Type	Base ASD	Notes
High-Speed Rail	15 meters	From the centerline
Conventional Rail	10 meters	From the centerline

In the context of railway networks, establishing Base Acceptable Safety Distances (ASDs) is crucial for mitigating the risks of wildfire ignitions. For high-speed rail lines, it is recommended to maintain a minimum clearance of 15 meters from the centerline. This buffer zone is particularly important for high-speed rails due to their increased potential for generating sparks or other ignition sources that could easily ignite adjacent vegetation or materials. For conventional rail lines, a slightly reduced safety margin is advised, with a minimum of 10 meters clearance from the centerline. This distance is considered adequate to safeguard against the typical risks associated with standard railway operations, including the potential for sparks or heated materials from the train to come into contact with nearby flammable substances. These ASD guidelines for railways are established to ensure a prudent balance between operational efficiency and the critical need to minimize the risk of wildfires, especially in areas prone to such events.

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Base ASD Guidelines for Other Infrastructure

Infrastructure Type	Base ASD	Notes
Pipelines	10 meters	On either side
Communication Lines	5-10 meters	Depending on pole height and type

When it comes to other types of infrastructure like pipelines and communication lines, specific Base Acceptable Safety Distances (ASDs) are crucial to minimize the risk of wildfire ignitions. For pipelines, which can be vulnerable to external heat sources and can exacerbate fire situations if breached, a minimum safety distance of 10 meters on either side is recommended. This clearance helps prevent the ignition of flammable materials close to the pipelines, reducing the risk of damage to the infrastructure and surrounding environment.

For communication lines, the recommended ASD varies between 5 and 10 meters, and this variation is dependent on the height and type of the poles used. The range allows for flexibility in implementation, taking into account the specific characteristics of the communication infrastructure. Shorter poles may require less clearance, while taller structures, which pose a higher risk of falling and causing damage in the event of a fire, necessitate a larger safety margin. These guidelines for pipelines and communication lines are designed to ensure operational safety and reduce the likelihood of these critical infrastructure contributing to the ignition or spread of wildfires.

Climate-Adjusted ASD Guidelines for Power Grids

Climate Type	Multiplier	Adjusted ASD for Power Grids
Dry Climate	1.3×	Base ASD × 1.3
Mild Climate	1.1×	Base ASD × 1.1
Wet Climate	0.9×	Base ASD × 0.9

In the realm of power grids, it's crucial to adjust Acceptable Safety Distances (ASDs) based on prevailing climate conditions, as these significantly influence wildfire risks. For areas with a dry climate, where the likelihood of wildfire ignition is typically higher due to drier vegetation and soil, it's recommended to increase the base ASD by a factor of 1.3. This means the safety distances around power lines should be expanded to 130% of the standard values to account for the increased fire risk in such environments.

Conversely, in mild climates, where the wildfire risk is more moderate, a smaller adjustment is suggested. Here, the base ASD should be increased by a factor of 1.1, or 110% of the standard safety distances. This slight increase acknowledges the potential for wildfires while balancing the need for practical infrastructure management.

In wet climates, characterized by higher moisture levels and a generally lower risk of wildfires, the base ASD can be reduced to 90% of the standard value. This adjustment reflects the reduced likelihood of vegetation ignition in such climates, allowing for a closer proximity of vegetation to power infrastructure without significantly increasing the risk of wildfires.

These climate-adjusted guidelines for power grids aim to provide a more nuanced approach to vegetation management and infrastructure safety, taking into account the specific environmental conditions of different regions. This adaptive strategy enhances the effectiveness of wildfire prevention measures in various climatic scenarios.

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Climate-Adjusted ASD Guidelines for Road Networks

Climate Type	Multiplier	Adjusted ASD for Road Networks
Dry Climate	1.2×	Base ASD × 1.2
Mild Climate	1.0×	Base ASD × 1.0
Wet Climate	0.8×	Base ASD × 0.8

For road networks, adapting the Acceptable Safety Distances (ASDs) to the local climate conditions is essential for effective wildfire risk management. In dry climates, where the risk of wildfire ignition is heightened due to lower humidity and drier vegetation, it's advisable to increase the base ASD by 20%, leading to an adjusted ASD of 1.2 times the base distance. This expanded clearance around roads aims to mitigate the higher fire risk in such arid conditions.

In mild climates, where wildfire risks are generally moderate, the base ASD can be maintained as is, with no additional adjustments. This reflects a balanced approach, considering the average likelihood of wildfire ignitions in these conditions.

Conversely, in wet climates, characterized by higher moisture levels and typically lower wildfire risks, the base ASD can be reduced. In these environments, it is recommended to decrease the ASD to 80% of the base value. This reduction accounts for the lower probability of wildfires in such moist conditions, allowing for a more condensed use of space around road networks without significantly increasing fire hazards.

These climate-adjusted guidelines for road networks provide a flexible approach to managing roadside vegetation and other potential fire sources. By tailoring safety distances to the specific climate of an area, road authorities can more effectively mitigate wildfire risks while efficiently managing roadside spaces.

Climate-Adjusted ASD Guidelines for Railways

Climate Type	Multiplier	Adjusted ASD for Railways
Dry Climate	1.3×	Base ASD × 1.3
Mild Climate	1.1×	Base ASD × 1.1
Wet Climate	0.9×	Base ASD × 0.9

For railway networks, adjusting the Acceptable Safety Distances (ASDs) in accordance with the prevailing climate conditions is a vital strategy for managing wildfire risks. In regions characterized by a dry climate, the susceptibility to wildfires is notably higher due to drier conditions. As a result, it's prudent to increase the base ASD by 30%, yielding an adjusted ASD of 1.3 times the base value. This extension of the safety margin around railway lines aims to mitigate the increased risk of fires in these arid areas.

In areas with a mild climate, where wildfire risks are generally balanced, the base ASD is recommended to be increased by 10%, resulting in an adjusted ASD of 1.1 times the base distance. This modest adjustment is designed to provide a margin of safety against wildfires while still maintaining efficient railway operations.

Conversely, in wet climates, known for their higher moisture content and lower incidence of wildfires, the base ASD can be reduced to 90% of the standard value. This decrease reflects the diminished risk of fire in such moist environments, enabling railways to operate with a smaller safety buffer without significantly heightening the risk of fire incidents.

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By tailoring the ASD values to the climatic conditions of each area, railway operators can effectively enhance their wildfire prevention measures. This climate-adjusted approach ensures that railway infrastructure is safeguarded against potential fire hazards while also accommodating the varying environmental conditions found across different regions.

Relative ASD Multipliers Based on Vegetation Type for Power Grids

Vegetation Type	Height	Multiplier
Shrubs	1m	1.2×
Shrubs	3m	1.5×
Pine Forest	5m	1.7×
Pine Forest	10m	2.0×
Hardwoods	5m	1.4×
Hardwoods	10m	1.6×

When managing wildfire risks around power grids, it's essential to consider the type and height of surrounding vegetation, as these factors significantly influence the required safety distances. The Acceptable Safety Distances (ASDs) need to be adjusted based on the specific vegetation characteristics. For shrubs, a multiplier is applied to the base ASD depending on their height. If the shrubs are 1 meter high, the base ASD should be increased by a factor of 1.2, and for shrubs reaching a height of 3 meters, the multiplier increases to 1.5.

For areas surrounded by a pine forest, the ASD adjustment is more pronounced due to the higher potential fire risk associated with these trees. For pine forests with a height of 5 meters, the base ASD should be multiplied by 1.7. If the pine trees grow up to 10 meters tall, the multiplier escalates to 2.0, reflecting the increased risk of fire spread in taller forests.

Similarly, for areas with hardwoods, the height of these trees also dictates the ASD multiplier. A 5-meter tall hardwood area requires the base ASD to be increased by a factor of 1.4. If the hardwoods reach a height of 10 meters, the multiplier should be 1.6. These adjustments are crucial for tailoring safety measures to the specific fire risks posed by different vegetation types and heights, ensuring a more effective approach to wildfire prevention around power grids.

Relative ASD Multipliers Based on Vegetation Type for Road Networks

Vegetation Type	Height	Multiplier
Shrubs	1m	1.1×
Shrubs	3m	1.3×
Pine Forest	5m	1.5×
Pine Forest	10m	1.8×
Hardwoods	5m	1.3×
Hardwoods	10m	1.5×

For road networks, the application of Relative Acceptable Safety Distances (ASDs) must be adjusted based on the type and height of nearby vegetation, due to the varying levels of wildfire risks posed by different vegetative growths. For

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areas with shrubs, the base ASD is modified according to their height. When shrubs are 1 meter high, the ASD should be adjusted to 1.1 times the base value, whereas for shrubs that are 3 meters tall, the multiplier increases to 1.3. This adjustment is essential for maintaining a safe buffer zone between the road and potential fire hazards.
In regions where pine forests are adjacent to roads, a higher ASD multiplier is required due to the increased risk of fire ignition and spread associated with pine trees. For pine forests that are 5 meters tall, the ASD should be 1.5 times the base distance. This multiplier grows to 1.8 for pine forests reaching 10 meters in height, acknowledging the heightened fire risk in taller pine forests.
Similarly, areas alongside roads that are surrounded by hardwoods necessitate adjustments in the ASD based on the height of the trees. For hardwoods that are 5 meters tall, the ASD should be increased to 1.3 times the base value, and for 10-meter-tall hardwoods, the multiplier should be 1.5. These modifications in safety distances, tailored to the specific type and height of vegetation, are crucial for effectively mitigating the risk of wildfires along road networks.

Relative ASD Multipliers Based on Vegetation Type for Railways

Vegetation Type	Height	Multiplier
Shrubs	1m	1.2×
Shrubs	3m	1.4×
Pine Forest	5m	1.6×
Pine Forest	10m	1.9×
Hardwoods	5m	1.3×
Hardwoods	10m	1.5×

For railway networks, adjusting the Acceptable Safety Distances (ASDs) based on the surrounding vegetation type and height is crucial for effective wildfire risk management. The ASD multipliers vary with different vegetation characteristics to ensure a sufficient safety buffer around the railways.
In areas with shrubs near railway lines, the ASD needs to be adapted according to the shrub height. For shrubs that are 1 meter tall, the multiplier for the base ASD is set at 1.2 times. If the shrubs are 3 meters high, the multiplier is increased to 1.4 times the base ASD. This adjustment accounts for the potential fire risk from shorter vegetation.
For railway lines adjacent to pine forests, a higher multiplier is required due to the greater fire risk associated with these trees. A 5-meter tall pine forest necessitates a multiplier of 1.6 times the base ASD, while for a 10-meter tall pine forest, the multiplier should be 1.9 times. These higher multipliers reflect the increased risk of fire spread in taller pine forests.
Similarly, when railways run through areas with hardwoods, the ASD is adjusted based on the height of the trees. For hardwoods reaching a height of 5 meters, the multiplier is 1.3 times the base ASD. In cases where hardwoods grow to 10 meters, the multiplier increases to 1.5 times. These tailored adjustments to the ASD based on vegetation type and height are essential in reducing the likelihood of wildfire ignitions and ensuring the safety of railway infrastructure.

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4.4 Guidelines related to educational and social aspects

These guidelines aim to create a culture of fire safety awareness and proactive prevention, involving individuals, communities, and various organizations in a collective effort to reduce the incidence of wildfires.

4.4.1 Educational Initiatives

Awareness Campaigns

Implementing comprehensive awareness campaigns that educate the public about the common causes of wildfires and how to prevent them. This includes understanding the role of human activities such as campfires, cigarette disposal, and equipment use.

School Programs

Integrating wildfire education into school curricula will instill a sense of responsibility and knowledge about fire safety from a young age.

Community Workshops

Organizing workshops and seminars in communities, especially those in fire-prone areas, to discuss wildfire risks and prevention strategies.

4.4.2 Social Engagement

Community Involvement:

Encouraging community participation in creating and maintaining defensible spaces around properties, which can act as a buffer and slow the spread of wildfires.

Volunteer Groups for fire prevention

Forming volunteer groups that can assist in fire prevention efforts, such as clearing brush or disseminating information.

Partnerships for the development of fire prevention plans

Establishing partnerships between local governments, fire departments, and residents to develop and implement fire prevention plans tailored to the specific needs of the area.

4.4.3 Behavioral Changes

Promoting Safe Practices

Advocating for safe outdoor practices, such as ensuring campfires are fully extinguished and avoiding the use of fireworks in dry areas.

Reporting Suspicious Activities

Encouraging the reporting of illegal or suspicious activities that could lead to wildfires, such as arson.

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Adopting Firewise Landscaping

Educating homeowners on choosing fire-resistant plants and materials for landscaping to reduce the risk of ignition.

4.4.4 Communication Strategies

Social Media Campaigns

Utilizing social media platforms to reach a wider audience with messages about wildfire prevention and safety tips.

Public Service Announcements (PSAs)

Broadcasting PSAs on television and radio to remind the public of the dangers of wildfires and how to prevent them.

Signage

Placing signs in high-risk areas to warn about the current fire danger level and to provide quick tips on preventing wildfires.

5 Conclusions

Addressing forest fire ignitions requires a multifaceted and integrated approach, engaging a diverse array of stakeholders, including governments, communities, landowners, industries, and researchers. This comprehensive framework, enriched by insights from the FirEURisk project, underscores the importance of mitigating forest fire ignitions, particularly those stemming from human activities. The guidelines offer practical and well-organized recommendations, covering a broad spectrum of aspects, including legal, technical, educational, and social measures, all aimed at reducing human-caused wildland fire ignitions.

The methodology behind these guidelines is robust, combining a literature review, data analysis, focus group discussions, and expert judgement. This has led to the development of detailed guidelines, such as the climate-adjusted Acceptable Safety Distances (ASDs) for various infrastructure, which are essential for a tailored approach to wildfire risk management. These guidelines emphasize the need for strategic and region-specific measures in fire management, underpinned by a strong foundation of public awareness and data-driven strategies.

The FirEURisk project's findings have been pivotal in shaping a strategic framework that not only aims to safeguard natural resources and human interests but also contributes significantly to the sustainable management of forest ecosystems. The framework calls for a holistic approach encompassing targeted infrastructure safety measures, specific regional fire management strategies, comprehensive public awareness campaigns, and the integration of technological innovations. There's a pronounced emphasis on adapting these strategies to the changing dynamics of climate and the environment, reflecting a proactive and forward-thinking approach to wildfire management.

The document provides an insightful overview of the legislative and institutional approaches adopted across Europe for mitigating wildfire risks, particularly around critical infrastructure. It highlights the diverse and complex nature of these approaches, stressing the importance of ongoing compliance, technological integration, and environmental adaptability. Furthermore, it delves into the challenges and effectiveness of current strategies, offering general recommendations within the FirEURisk project's scope.

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Key to advancing these efforts are strategies like standardized monitoring and reporting across EU nations, the integration of cutting-edge technologies such as AI and remote sensing for effective wildfire risk management, and fostering cross-sector collaboration. Additionally, there's a strong call for public awareness initiatives and education programs, which are instrumental in fostering a culture of responsibility and proactive prevention, especially in areas surrounding critical infrastructure.

In conclusion, this comprehensive document serves as a roadmap for reducing forest fire risks, emphasizing the need for ongoing innovation, collaboration, and adaptation to mitigate the impacts of forest fires effectively. By implementing these guidelines, stakeholders can play a crucial role in preserving ecosystems, protecting human lives and properties, and promoting sustainable forest management. The recommendations, deeply rooted in scientific research and practical insights, highlight the critical need for a proactive and collaborative approach to addressing human-caused forest fire ignitions, paving the way for safer and more resilient forest ecosystems.

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ANNEXES

Annex A: FirEUrisk Consortium Questionnaire

FirEUrisk Consortium Questionnaire:
National Legislation on Forest Fire Prevention Linked to Critical Infrastructure

Respondent Information

- **Country of Representation: Please specify your country:**

Data on Wildfires and Critical Infrastructure

- **Annual Statistics on Wildfires Attributed to Critical Infrastructure:**
  - **Please provide the number of wildfires in your country over the past year that were attributed to critical infrastructure.**
  - **If available, include a brief summary of the trends observed over the last five years.**

- **Critical Infrastructure Contributing to Fire Ignitions:**
  - **Identify the types of critical infrastructure in your country that have most frequently been associated with the ignition of wildfires. Examples include power lines, transportation networks, industrial complexes, etc.**
  - **Provide any available data or case studies that illustrate these links.**

National Legislation and Regulations

- **Existing Laws and Regulations:**
  - **Describe the national laws or regulations in place aimed at preventing forest fires specifically related to critical infrastructure. Please provide the specific name or reference of each law or regulation.**

  - **Include information on the scope of these regulations, including the types of critical infrastructure covered, the specific preventive measures required, and the responsible authorities for enforcement.**

  - **Describe the mechanisms for enforcing these regulations, including any penalties or sanctions for non-compliance.**

- **Effectiveness and Challenges:**
  - **Assess the effectiveness of the current laws and regulations in preventing forest fires caused by critical infrastructure.**

- Identify any challenges or gaps in the existing legislative framework, such as insufficient coverage of critical infrastructure types, unclear requirements, or inadequate enforcement mechanisms.

- Gap Analysis:
  - Based on the information provided, identify any gaps or areas for improvement in the national legislation and regulations related to forest fire prevention and critical infrastructure.
  - Suggest potential amendments or new regulations that could enhance the effectiveness of forest fire prevention efforts.

Additional Comments

- Please provide any additional comments or insights related to the intersection of critical infrastructure and forest fire risks in your country.

- Share any best practices or successful initiatives that have been implemented to mitigate the fire risk associated with critical infrastructure.

- **Suggest areas for further research or collaboration to improve forest fire prevention and critical infrastructure safety.**

Date:

Place:

Annex B: FirEUrisk Consortium Questionnaire / Completed Questionnaires

FirEUrisk Consortium Questionnaire:

National Legislation on Forest Fire Prevention Linked to Critical Infrastructure

Respondent Information

- Country of Representation: Please specify your country: **CROATIA**

Data on Wildfires and Critical Infrastructure

- Annual Statistics on Wildfires Attributed to Critical Infrastructure:
  - Please provide the number of wildfires in your country over the past year that were attributed to critical infrastructure.

There are no records regarding cause of fire, only statistics regarding type of fire – wildfire, vegetation fire and vehicle fire

Statistics for 2022 and 2021 are given in the table :

Report: National firefighting command and coordination centre 193 about fires from 01.01. to

TYPES OF FIRES	OUTDOOR FIRES	WILDFIRES	BURNT SURFACE ha	FIRE IN/ON THE BUILDING	VEHICLE FIRE	TOTAL NUMBER OF FIRES	NUMBER OF FATALITIES REPORTED
TOTAL NUMBER	8666	5420	24209	4515	906	14087	31

Report: National firefighting command and coordination centre 193 about fires from 01.01. to

TYPES OF FIRES	OUTDOOR FIRES	WILDFIRES	BURNT SURFACE ha	FIRE IN/ON THE BUILDING	VEHICLE FIRE	TOTAL NUMBER OF FIRES	NUMBER OF FATALITIES REPORTED
TOTAL NUMBER	10541	7891	62426	4021	913	15475	35
							(Firefighter 1)
DATA COMPARATION FOR 01.01. - 31.12. 2022. / 2021.	21,64% ↑	45,59% ↑	157,86% ↑	-10,94% ↓	0,77% ↑	9,85% ↑	12,90% ↑

When comparing the total number and burned areas between 2021 and 2022 we can see significant increase in 2022. However, when we compare first 8 months of 2003 we can see significant decrease of number of wildfires and particularly burnt surface:

Report: National firefighting command and coordination centre 193 about fires from 01.01. to

TYPES OF FIRES	OUTDOOR FIRES	WILDFIRES	BURNT SURFACE ha	FIRE IN/ON THE BUILDING	VEHICLE FIRE	TOTAL NUMBER OF FIRES	NUMBER OF FATALITIES REPORTED
TOTAL NUMBER	8.156	6.421	55.305	2.644	531	11.331	25
							(Vatrogasaca 1)

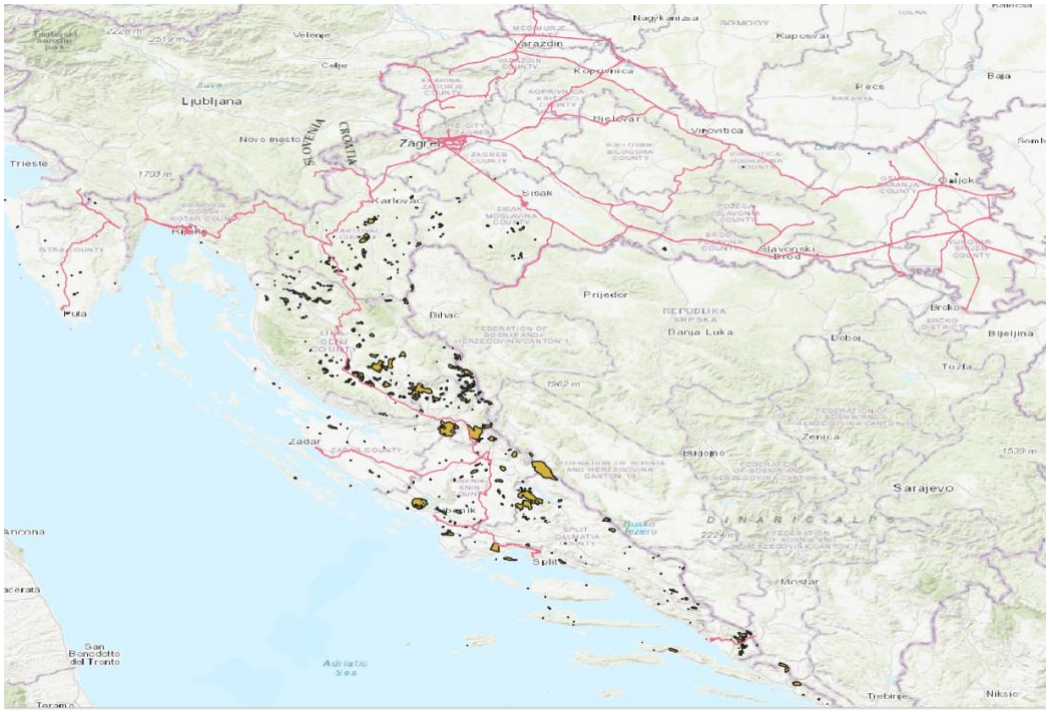
Report: National firefighting command and coordination centre 193 about fires from 01.01. to

TYPES OF FIRES	OUTDOOR FIRES	WILDFIRES	BURNT SURFACE ha	FIRE IN/ON THE BUILDING	VEHICLE FIRE	TOTAL NUMBER OF FIRES	NUMBER OF FATALITIES REPORTED
TOTAL NUMBER	3.099	1.892	3.767	2.372	542	6.013	14
DATA COMPARATION FOR 01.01. - 1.8. 2022. / 2023.	-62,00%	-70,53%	-93,19%	-10,29%	2,07%	-46,93%	-44,00%

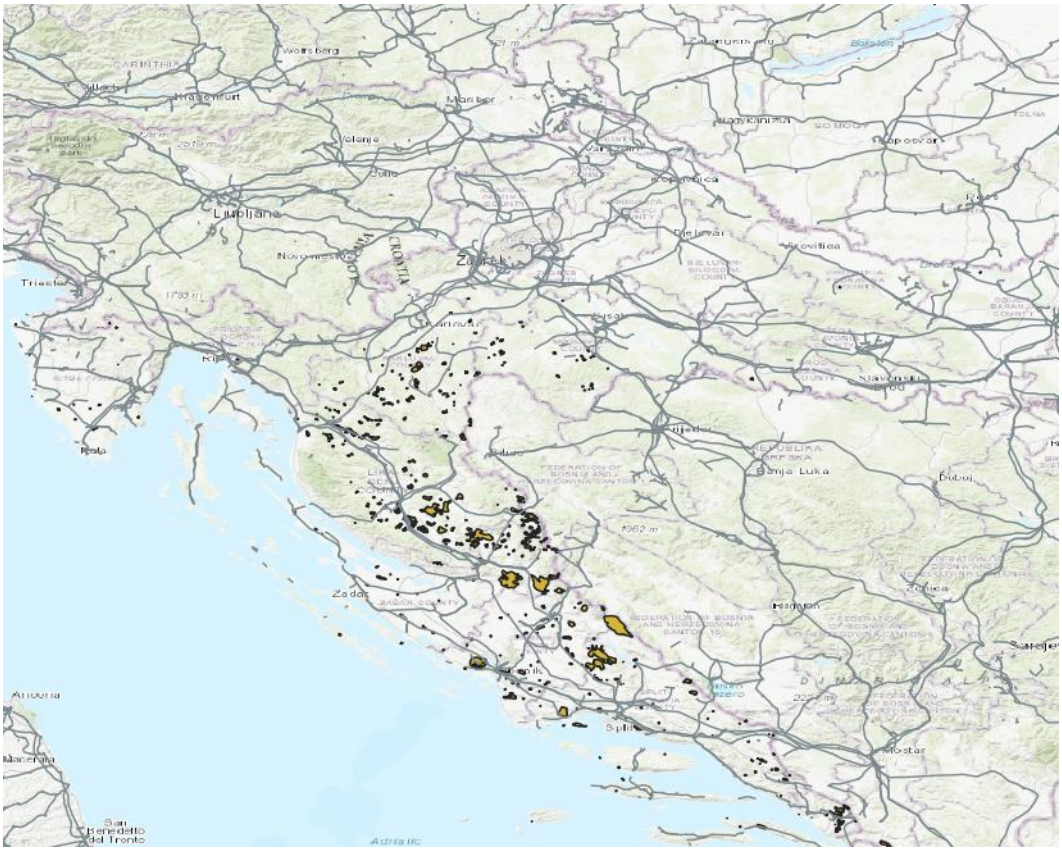
  - If available, include a brief summary of the trends observed over the last five years.

According to EFFIS records (https://effis.jrc.ec.europa.eu/apps/effis.statistics/estimates/HRV) Over the last five years there are no clear trends in burned areas or number of fires. However, from longer records e can notice the cyclic occurence of higher burned areas and numbers of fires every 5 years. In 2017 an extreme fire season wih several extreme fires occured. After that year

significant investments in firefighting capacity has been made by the government so that regardless of climate changes no larger damages has been observed afterwards.



Overlay od effis burned areain last 5 years and rail network



Overlay of ESRI burned area with powerlines

- Critical Infrastructure Contributing to Fire Ignitions:
    - Identify the types of critical infrastructure in your country that have most frequently been associated with the ignition of wildfires. Examples include power lines, transportation networks, industrial complexes, etc.

Unfortunately in fire records there are no information about outdoor fires and there connection with infrastructure, but from our experience most fire ignitions are connected with human activities, particularly agricultural activities and lightnings. There are a certain small number of fires caused by power lines and a certain number, particularly in Split-Dalmatia County connected with sparking from the railways. It is difficult to estimate their influence in fire ignition, but it is not more than few percentages.

    - Provide any available data or case studies that illustrate these links.

Fires caused by railway:
17.7.2010. - https://www.24sata.hr/news/vlak-je-naglo-zakocio-te-je-uz-tracnice-zapalio-travu-182560
1.08.2013 - https://www.vecernji.hr/vijesti/vlak-zapalio-novi-pozar-u-kastelima-gasila-ga-i-2-air-traktora-592852
17.08.2013 - https://www.tportal.hr/vijesti/clanak/crni-dim-nadvio-se-nad-splitom-gradani-se-zale-na-otezano-disanje-20130817/print
28.02.2019 - https://varazdinski.net.hr/vijesti/crna-kronika/3347869/pozar-kod-zeljeznickog-mosta-na-dravi-zapalila-se-sikara-i-trava/

Fire caused by power lines:
05.06.2011 - https://www.vecernji.hr/vijesti/zice-dalekovoda-zapalile-travu-pozar-gase-i-dva-kanadera-296758

National Legislation and Regulations

- Existing Laws and Regulations:
    - Describe the national laws or regulations in place aimed at preventing forest fires specifically related to critical infrastructure. Please provide the specific name or reference of each law or regulation.

There are very well developed legislative concerning firefighting. The base documents are:
- Low on Firefighting (in Croatian: Zakon o vatrogastvu) from 2019 - https://narodne-novine.nn.hr/clanci/sluzbeni/2019_12_125_2486.html
- Low on Fire Protection (in Croatian: Zakon o zaštiti od požara) from 2010 - https://narodne-novine.nn.hr/clanci/sluzbeni/2010_07_92_2588.html

According to them every year a special legal document is published named
- **Program of activities in the implementation of special fire protection measures of interest to the Republic of Croatia** (in Croatian Program aktivnosti u provedbi posebnih mjera zaštite od požara od interesa za Republiku Hrvatsku) – document for 2023 is on this link - https://hvz.gov.hr/UserDocsImages/dokumenti/Program%20aktivnosti/191%20-%209%20Program%20aktivnosti%202023..pdf

It defines everything connected with fire protection measures.

- Include information on the scope of these regulations, including the types of critical infrastructure covered, the specific preventive measures required, and the responsible authorities for enforcement.

On page 6 of **Program of activities in the implementation of special fire protection measures of interest to the Republic of Croatia** (https://hvz.gov.hr/UserDocsImages/dokumenti/Program%20aktivnosti/191%20-%209%20Program%20aktivnosti%202023..pdf) in 8a it is written:
8. a) Local self-government units, public institutions of national parks and Hrvatske šume d.o.o. are obliged, in cooperation with the competent county/City of Zagreb fire brigades, to update, that is, to create monitoring, guarding and patrolling plans and to implement the prescribed fire protection measures in endangered areas, buildings and areas along railway and road routes for their area of responsibility. The aforementioned entities are required to pay particular attention to the maintenance of access roads for emergency vehicles to critical infrastructure (railways, highways, power plants, water pumping stations, forests, gas pipelines, oil pipelines, transmission lines, etc.).

- Describe mechanisms for enforcing these regulations, including any penalties or sanctions for non-compliance.

In this document there is nothing connected with enforcements and penalties.

- Effectiveness and Challenges:
  - Assess the effectiveness of the current laws and regulations in preventing forest fires caused by critical infrastructure.

It is quite difficult to assess the effectiveness, but the fact is that the fire preventive actions and firefighting service are very well organised, therefore in 2003 we have much lower burned area, but also significant decrease of wildfires.

  - Identify any challenges or gaps in the existing legislative framework, such as insufficient coverage of critical infrastructure types, unclear requirements, or inadequate enforcement mechanisms.

We thing that lows and legislative acts are quite appropriate.

- Gap Analysis:
  - Based on the information provided, identify any gaps or areas for improvement in the national legislation and regulations related to forest fire prevention and critical infrastructure.

Overall the legislation is good. Of course improvement could be done and we notice that comparing **Program of activities …** in different years. For example couple of years ago monitoring was defined only as human monitoring, but now also video monitoring is introduced.

  - Suggest potential amendments or new regulations that could enhance the effectiveness of forest fire prevention efforts.

Difficult to do that.

Additional Comments

- Please provide any additional comments or insights related to the intersection of critical infrastructure and forest fire risks in your country.

- Share any best practices or successful initiatives that have been implemented to mitigate the fire risk associated with critical infrastructure.

- Suggest areas for further research or collaboration to improve forest fire prevention and critical infrastructure safety.

Date: January, 30 2024
Place:

Fireurisk Consortium Questionnaire:
National Legislation on Forest Fire Prevention Linked to Critical Infrastructure

Respondent Information

- Country of Representation: Please specify your country: **CYPRUS**

Data on Wildfires and Critical Infrastructure

- Annual Statistics on Wildfires Attributed to Critical Infrastructure:
  - Please provide the number of wildfires in your country over the past year that were attributed to critical infrastructure.

There were recorded 232 wildfires and 27 (12%) of those were cause by power lines resulting to approximate 83ha of burnt area (out of 1016.5459ha)

  - If available, include a brief summary of the trends observed over the last five years.

Power cables is the only reported by the Forest Department as cause of wildfires related to critical infrastructure.
For instance in a report available from the Forest Department for the years 2000-2021 5% (35 fires) of the wildfires are recorded to be cause by power cables.
https://www.moa.gov.cy/moa/fd/fd.nsf/F430338BA7D4AC57C2257E5000330A18/$file/%CE%A3%CF%84%CE%B1%CF%84%CE%B9%CF%83%CF%84%CE%B9%CE%BA%CE%AC%20%CF%83%CF%84%CE%BF%CE%B9%CF%87%CE%B5%CE%AF%CE%B1%20%CE%B4%CE%B1%CF%83%CE%B9%CE%BA%CF%8E%CE%BD%20%CF%80%CF%85%CF%81%CE%BA%CE%B1%CE%B3%CE%B9%CF%8E%CE%BD%20%CE%B3%CE%B9%CE%B1%20%CF%84%CE%B7%CE%BD%20%CF%80%CE%B5%CF%81%CE%AF%CE%BF%CE%B4%CE%BF%202000-2021.pdf

In another report in the media for the year 2022 7% (3) of the total recorded wildfires for the year are reported to be caused by power lines.

https://www.kathimerini.com.cy/gr/kypros/edeixan-idi-ta-dontia-toys-oi-pyrkagies-ta-prwta-stoixeia-toy-2023-pinakes

Unfortunately, the Cypriot Forest Department it is not very responsive and consisent with the reporting.

- Critical Infrastructure Contributing to Fire Ignitions:
  - Identify the types of critical infrastructure in your country that have most frequently been associated with the ignition of wildfires. Examples include power lines, transportation networks, industrial complexes, etc.

Power lines

- Provide any available data or case studies that illustrate these links.

https://newcyprusmagazine.com/forestry-department-cyprus-accuses-electricity-authority-cyprus-eac-responsible-summer-wildfires-paphos-forest-palaichori-area-inadequate-maintenance-outdated-uninsulated-wires/

https://www.offsite.com.cy/eidiseis/koinonia/telos-ta-gymna-kalodia-tis-aik-mesa-sta-dasi-tha-mpoyn-alla-me-monosi

https://news.rik.cy/article/2023/7/25/se-kinetopoiese-oi-arkhes-kai-sten-kupro-gia-antimetopise-purkagion-upo-elegkho-e-purkagia-ste-gialia/
https://www.moa.gov.cy/moa/fd/fd.nsf/C7940ABF1C1A3D41C2257E5000330827/$file/Forest%20fire%20statistics%20for%20the%20period%202000-2021.pdf

National Legislation and Regulations

- Existing Laws and Regulations:
  - Describe the national laws or regulations in place aimed at preventing forest fires specifically related to critical infrastructure. Please provide the specific name or reference of each law or regulation.

There is not an exclusive law or regulation in place for the preventing forest fires related to critical infrastructure. The only law available (Οι περί Δασών (Άδειες, Χρήση Δασικών Δρόμων και Εξαγωγή Δασικών Προϊόντων) Κανονισμοί του 2012) it states the procedures for applyig for permit in order to perform any actions inside the boundaries of a forestry area inlcuding among others cutting wood, setting up a camping area, performing car racing. The permisions and terminations of those is under the responsibility of the Director of the Forest Department.

https://www.moa.gov.cy/moa/fd/fd.nsf/all/B075B096E31148A8C225814000428970/$file/%CE%9F%CE%99%20%CE%A0%CE%95%CE%A1%CE%99%20%CE%94%CE%91%CE%A3%CE%A9%CE%9D%20%CE%9A%CE%91%CE%9D%20133-2012.pdf?openelement

In the email sending this questionnari I will also attanch a study performed by the Department of Forest on 2006 where a cause of fires due to infrastructures it is not mentioned.

  - Include information on the scope of these regulations, including the types of critical infrastructure covered, the specific preventive measures required, and the responsible authorities for enforcement.

Not available

- Describe the mechanisms for enforcing these regulations, including any penalties or sanctions for non-compliance.

Due to the recent wildfires caused by power cables it has been decided by the Cypriot government that all the power cables passing through forest areas to be covered with special insulation material. To identify these areas and organise the relevant actions it has been decided by the Minstry of Argiculture to establish workign groups with representatives from the ministry, the EAC-national electricity provider, forest departnet and fire brigade. https://www.kathimerini.com.cy/gr/kypros/systasi-monimis-omadas-ergasias-gia-meiosi-kindynoy-pyrkagias-apo-kalwdia https://news.rik.cy/article/2023/8/5/ephikte-e-antimetopise-ton-problematon-apo-ta-gumna-kalodia-delonoun-aek-kai-tmema-dason/

- Effectiveness and Challenges:
  - Assess the effectiveness of the current laws and regulations in preventing forest fires caused by critical infrastructure.

Not possible since there are no laws in place.

  - Identify any challenges or gaps in the existing legislative framework, such as insufficient coverage of critical infrastructure types, unclear requirements, or inadequate enforcement mechanisms.

It should be establishing a relevant legislation.

- Gap Analysis:
  - Based on the information provided, identify any gaps or areas for improvement in the national legislation and regulations related to forest fire prevention and critical infrastructure.

It should be establishing a relevant legislation.

  - Suggest potential amendments or new regulations that could enhance the effectiveness of forest fire prevention efforts.

It should be establishing a relevant legislation.

Additional Comments

- Please provide any additional comments or insights related to the intersection of critical infrastructure and forest fire risks in your country.

N/A

- Share any best practices or successful initiatives that have been implemented to mitigate the fire risk associated with critical infrastructure.

The only recorded methodology available at the moment is the decision to cover the exposed power cables with appropiate insulation material.

- Suggest areas for further research or collaboration to improve forest fire prevention and critical infrastructure safety.

An updated legislation and enforcemnet of it should come in place soon. Since the main cause of wildfires related with infrastusture it is proven by the incidents to to be the exposed power cables those should be covered appropiately or being re-located or hidden underground, depending on the flexibility at each forest area. However, the legislation should also identify and cover other existing or future infrasturctures which might cause wildfires. For instance gas pipes (if natural gas will be distributed by pipes/ducts through the island, water treament plants, and trasportation.

Date: 28/03/2024
Place: European University Cyprus

Fireurisk Consortium Questionnaire:
National Legislation on Forest Fire Prevention Linked to Critical Infrastructure

Respondent Information

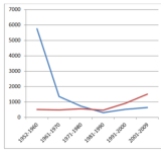
- Country of Representation: Please specify your country: **FINLAND**

Data on Wildfires and Critical Infrastructure

- Annual Statistics on Wildfires Attributed to Critical Infrastructure:
  - Please provide the number of wildfires in your country over the past year that were attributed to critical infrastructure.

Annual statistics on wildfires/groundfires gives the total number of 2571. In Finland, the average area of fires is typically small, less than 1 hectare , but of course some bigger areas than 1 ha have also burned. The total area burned is less than 1000 ha. These are typically not attributed to critical infrastructure, and we have not found any data available covering that information.

  - If available, include a brief summary of the trends observed over the last five years.



Blue: burned area, red: number of fires (historical data). Nowadays it is around 2000 every year but the total area is still normally under 1000 ha. Very rarely critical infrastructure is affected.
Note that the area has diminished dramatically from 1950-1960 numbers.

  - Identify the types of critical infrastructure in your country that have most frequently been associated with the ignition of wildfires. Examples include power lines, transportation networks, industrial complexes, etc.

There are some odd cases; One example is the Ylistaro wildfire in 2010, which spread close to the Seinäjoki Airport, risk being the air traffic being disrupted or the airport having to close.Another example in 2018, one fire threatened to spread near several industrial areas. In this scenario, there was a risk of industrial facilities having to evacuate employees or suspend their production for safety reasons.

  - Provide any available data or case studies that illustrate these links.

article in Finnish:
https://yle.fi/a/3-12039884

National Legislation and Regulations

- Existing Laws and Regulations:
    - Describe the national laws or regulations in place aimed at preventing forest fires specifically related to critical infrastructure. Please provide the specific name or reference of each law or regulation.

Forest Act (62/2017)
Rescue Act (379/2011)
Land Use and Building Act (132/1999)
Environmental Protection Act (527/2014)
Government Decree on Forest Fire Protection (684/2015)

    - Include information on the scope of these regulations, including the types of critical infrastructure covered, the specific preventive measures required, and the responsible authorities for enforcement.

While these laws and regulations do not explicitly target forest fires related to critical infrastructure, they establish a framework for managing forest fires and protecting public safety, including critical infrastructure assets. Local authorities, forestry agencies, and other stakeholders are responsible for implementing these regulations and taking appropriate measures to prevent forest fires and mitigate their impacts on critical infrastructure.

    - Describe the mechanisms for enforcing these regulations, including any penalties or sanctions for non-compliance.

The mechanisms involved are: Inspections and Monitoring, Permitting and Licensing,Public Awareness and Education, Coordination and Collaboration, Enforcement Actions and Penalties, Emergency Response and Crisis Management, Legal Proceedings
Overall, the enforcement of regulations aimed at preventing forest fires and protecting critical infrastructure in Finland involves a combination of proactive measures, public engagement, enforcement actions, and emergency response efforts to minimize fire risks and ensure public safety.

- Effectiveness and Challenges:
    - Assess the effectiveness of the current laws and regulations in preventing forest fires caused by critical infrastructure.

Overall, while Finland has comprehensive laws and regulations aimed at preventing forest fires and protecting critical infrastructure, their effectiveness ultimately depends on robust enforcement, proactive preventive measures, stakeholder engagement, and adaptability to evolving challenges. Continuous evaluation and refinement of regulations based on lessons learned from past experiences and emerging risks are essential for enhancing their effectiveness in the long term.

- Identify any challenges or gaps in the existing legislative framework, such as insufficient coverage of critical infrastructure types, unclear requirements, or inadequate enforcement mechanisms.

It may not provide a clear definition or comprehensive list of critical infrastructure types vulnerable to forest fires. Effective coordination and collaboration are crucial for mitigating fire risks to critical infrastructure.Strengthening enforcement mechanisms, increasing inspection frequency, and imposing stricter penalties for violations can enhance compliance with fire prevention requirements.The current legislative framework may not adequately address the evolving risks and vulnerabilities associated with climate change impacts on critical infrastructure.

- Gap Analysis:

Implementing standardized procedures and requirements for conducting comprehensive fire risk assessments specifically tailored to critical infrastructure could significantly improve preparedness and resilience.
Creating a centralized coordination mechanism tasked with overseeing and coordinating efforts to protect critical infrastructure from forest fires could streamline communication, resource allocation, and decision-making processes.

- Based on the information provided, identify any gaps or areas for improvement in the national legislation and regulations related to forest fire prevention and critical infrastructure.

Fire risk assessments for critical infrastructure, stricter vegetation management requirements, enhanced building codes and standards, improved monitoring and early warning systems, integrated land use planning and zoning regulations

- Suggest potential amendments or new regulations that could enhance the effectiveness of forest fire prevention efforts.

Additional Comments

- Please provide any additional comments or insights related to the intersection of critical infrastructure and forest fire risks in your country.

- Share any best practices or successful initiatives that have been implemented to mitigate the fire risk associated with critical infrastructure.

- Suggest areas for further research or collaboration to improve forest fire prevention and critical infrastructure safety.

Fireurisk Consortium Questionnaire:
National Legislation on Forest Fire Prevention Linked to Critical Infrastructure

Respondent Information

- Country of Representation: Please specify your country:

FRANCE

Data on Wildfires and Critical Infrastructure

- Annual Statistics on Wildfires Attributed to Critical Infrastructure:
    - Please provide the number of wildfires in your country over the past year that were attributed to critical infrastructure.

Unknown.
The national database BDIFF : Accueil (agriculture.gouv.fr) only provides general information for public. When investigated, the causes of fires are recorded on the database ; however this data has not been made available for us despite our request to do research.

    - If available, include a brief summary of the trends observed over the last five years.

General figures of fires over the past five years (source BDIFF)
2018 : 1928 fires, 4 035,56 ha
2019 : 2970 fires, 15 190 ha
2020 : 2949 fires, 11 220,6 ha
2021 : 2348 fires, 12 850,48 ha
2022 : 4393 fires, 59 014,36 ha
Since 2017, we see an increase in the number of fires in France. They are impacting new areas such as the north of the country and reinforcing in the Mediterranean region. The 2022 fire season was the second worst year in France after 2003 major European heat wave with 73 000 ha.

- Critical Infrastructure Contributing to Fire Ignitions:
    - Identify the types of critical infrastructure in your country that have most frequently been associated with the ignition of wildfires. Examples include power lines, transportation networks, industrial complexes, etc.

Today, the data available on the causes of fires in France are diluted into 4 categories, making it impossible to clearly understand which ignition sources is the most important. Concerning the critical infrastructures, field experience has shown that :

- Powerline are often involved in fire ignition during high wind period or heat wave
- Fire along the railway transportation network are frequent, but less common than the freeway network which account for a large proportion of fires due to car fires or cigarettes. Nevertheless, fires along railroads are often multi-sited, with each ignition point several hundred meters apart, making first-instance fire-fighting difficult.

- Provide any available data or case studies that illustrate these links.

Concerning the railways, the law indicates to clear any vegetation 20 meters away of the track to prevent trees to fall on the railway.
Fore industries, the defensible space should be 100 meters deep.
Concerning the power line, technical rules are available in this link. The vegetation clearing depends on the voltage and location of power lines.
Low-voltage lines - 230 / 400 volts

- In built-up areas: 2 m wide, minimum height of 2 m between insulator and tree
- Outside built-up areas: 3-meter width, minimum 2-meter height between insulator and tree

High-voltage (HV) lines - 15 or 20,000 volts

- Rigid insulators: 4 meters wide and 3 meters high minimum between shaft and insulator.
- Suspended insulators: 5 meters wide and 3 meters high minimum between tree and insulator.

One of the recent big fire in Mediterranean region due to critical infrastructure occurred in 2022 in Bouches-du-Rhône. 32 ignition points were reported after a default on a train transporting passengers. Sparks ignited along 15 km of railway which 8,5 km were touching the Montagnette forest. The fire covered 1,451.5 ha of the 3,428 ha forest. One firefighter perished due to heartattack.



National Legislation and Regulations

- Existing Laws and Regulations:
    - Describe the national laws or regulations in place aimed at preventing forest fires specifically related to critical infrastructure. Please provide the specific name or reference of each law or regulation.

In accordance with Article L131-16 of the French Forestry Code, when there are woods and forests less than 20 meters from the boundary of a railroad or power line (Article L134-11), the infrastructure manager has the right to clear a longitudinal strip of undergrowth 20 meters wide from the outside edge of the track.

    - Include information on the scope of these regulations, including the types of critical infrastructure covered, the specific preventive measures required, and the responsible authorities for enforcement

    - Describe the mechanisms for enforcing these regulations, including any penalties or sanctions for non-compliance.

In penal terms, failure to comply with vegetation clearing is punishable by a fifth-class fine of up to 1,500 euros, or 3,000 euros in the event of a repeat offence (Art. R. 163-3 French Forestry Code). In administrative terms, the mayor or prefect can issue a formal notice to the person obliged to clear brushwood to carry out the clearing work, or to maintain the property in a cleared state. If the latter fails to comply within the allotted time, the prefect may impose an administrative fine of up to 50 euros per square meter. Penalties can be much heavier in the event of destruction of another person's property as a result of failure to comply with the OLD. They can reach 2 years' imprisonment and a fine of 30,000 euros for the destruction of a forest, 3 years' imprisonment and a fine of 45,000 euros if the violation of the obligation is deliberate. Or up to 5 years' imprisonment and a 100,000-euro fine in the case of bodily injury, or ten years' imprisonment and a 150,000-euro fine in the case of death (Penal Code., Art. 322-5).

- Effectiveness and Challenges:
    - Assess the effectiveness of the current laws and regulations in preventing forest fires caused by critical infrastructure.

    - Identify any challenges or gaps in the existing legislative framework, such as insufficient coverage of critical infrastructure types, unclear requirements, or inadequate enforcement mechanisms.

There are 3 main challenges :

1. Ownership of the land: the power network company don't own the land below the powerlines. As a result, the company may not be authorised to clear the land below the lines.
2. Cost. Clearing everything and maintaining clearance every year is too expensive to be affordable
3. Environmental constrain : suppressing all vegetation along the lines is not nature-friendly

- Gap Analysis:

Since it is too difficult, too expensive and not nature-friendly to clear the vegetation evrywhere along the powerlines, railways, and so on, priority areas should be clearly evaluated (risk analysis methods) and divulgated to network operators.
This priority mapping could be done :

1. by the government when declining the fire risk planification at local level
2. or by the operators supported by expert consultant

  - Based on the information provided, identify any gaps or areas for improvement in the national legislation and regulations related to forest fire prevention and critical infrastructure.

  - Suggest potential amendments or new regulations that could enhance the effectiveness of forest fire prevention efforts.

- Mapping the priority areas
- Tax credit for individuals for expenses incurred in clearing undergrowth.
- Compulsory deductible in insurance contracts for non-compliance with legal brush clearance obligations, and doubling of the maximum amount of this deductible.

Additional Comments

- Please provide any additional comments or insights related to the intersection of critical infrastructure and forest fire risks in your country.

In France, 316 high risk industries (called Seveso) are located in at risk area to wildfire.
In 2050, in a median emissions scenario [IPCC RCP 4.5], three quarters of the 316 French Seveso facilities located near wooded areas will be exposed to a high fire risk for at least 10 days a year, compared with one third in 2000", warns a recent study published in 2022 by the climate risk analysis company Callendar. On average, the risk of fire near these facilities will increase by "around 50%".

- Share any best practices or successful initiatives that have been implemented to mitigate the fire risk associated with critical infrastructure.

- Suggest areas for further research or collaboration to improve forest fire prevention and critical infrastructure safety.

Date: 19/03/2024
Place: Aix-en-Provence; France

Fireurisk Consortium Questionnaire:

National Legislation on Forest Fire Prevention Linked to Critical Infrastructure

Respondent Information

- Country of Representation: Please specify your country: **ITALY**

Data on Wildfires and Critical Infrastructure

- Annual Statistics on Wildfires Attributed to Critical Infrastructure:
  - Please provide the number of wildfires in your country over the past year that were attributed to critical infrastructure.

24% of fire ignitions are located near road networks. The main reason for this is that malicious or negligent ignitions have higher probability to occur near road.
A study of Fire Brigades reports that:
0.4% of events are due to trains (Sparks caused by the friction of wheels);
7.8% of events are due to cigarette butts (part of the 24% mentioned above);
0.8% of events are due to power line.

In the last five year burnt areas increased from 39650 ha (in 2019) to 107022 ha (in 2023) with an average increase of 15.2%. No statistics on the causes for each year are available.

- Critical Infrastructure Contributing to Fire Ignitions:
  - Identify the types of critical infrastructure in your country that have most frequently been associated with the ignition of wildfires. Examples include power lines, transportation networks, industrial complexes, etc.
  - Provide any available data or case studies that illustrate these links.

As said above the 24% of the ignitions are localized near road network. No statistics are, in general, available for other infrastructures.

However, a video shows the possible genesis of the fire broke out in the summer of 2022 in the Carso area and which would represent the proof of how the flames originated near the railway line. This emerges from the investigation documents, conducted by the Regional Forestry Corps. The investigation points the finger at the railway line and its users. The train in question traveled in the direction of the Trieste on the morning of July 19, 2022. The convoy proceeded uphill. A few seconds after the passage of the train, the cameras take the fire that flares up. Between 1990 and 2022, according to a study of the Fire Brigades (dott. Massimo Stroppa), in the railway area between Monfalcone and Sistiana at least 90 fires broke out.

National Legislation and Regulations

- Existing Laws and Regulations:
    - Describe the national laws or regulations in place aimed at preventing forest fires specifically related to critical infrastructure. Please provide the specific name orreference of each law or regulation.

LEGGE 21 novembre 2000 , n. 353: Legge-quadro in materia di incendi boschivi.

Art. 3. Piano regionale di previsione, prevenzione e lotta attiva contro gli incendi boschivi.

The regions approve the regional plan for the programming of forecasting, prevention and active fighting activities against forest fires, on the basis of guidelines and directives approved, within sixty days from the date of entry into force of this law.

L.R. (Legge Regionale) 28 Ottobre 2002, n. 39: Norme in materia di gestione delle risorse forestali

Art. 93. (Misure per la prevenzione degli incendi nelle aree boscate)

1. It is always forbidden to light fires during the year for:
2. Prior to the fire risk period and for its duration, interested parties must:

a) in agricultural areas adjacent to woods, if there is continuity in the vegetal cover up to the wooded area and bordering a municipal or higher road that hosts extra-local traffic, create a firebreak of no less than 5 meters in width without any vegetation bordering the road or the forest;

b) in areas pertaining to municipal or higher asphalted roads that host extra-local traffic and to railways, adjacent to woods or less than 20 meters away from the edge of the projection on the ground of the foliage of the plants at the edge of the forest, avoid all possible outbreak and spread of fires, providing, within a band of at least 20 meters in width, which must also include the relevant band:

3. The managers of electrical substations, prior to the fire risk period, must clean up the herbaceous and shrubby species in the areas pertaining to the substations for a radius of no less than 10 metres. If fire has to be used, communication must be sent to the Station Command of the State Forestry Corps responsible for the territory.
4. The material resulting from the operations referred to in paragraphs 2 and 3 and the other dead material susceptible to catching fire, however present in the band, can be reduced to flakes and fragments (chips) and released on the fall bed or can be removed.
5. The public bodies competent for the management of the appurtenances referred to in paragraph 2, letter b) may stipulate agreements with the owners or in any case holders of the adjacent and contiguous areas for the purposes of management and maintenance of the relevant area.

Art. 95 (Cautela per l'impianto di fornaci e fabbriche nei boschi. Discariche)

1. The installation of factories of any kind that cause fire danger within the woods or less than 200 meters from them is permitted subject to authorization from the competent body.
2. The provisions referred to in paragraph 1 also apply to the creation of landfills of any kind that cause a fire risk inside the woods or at less than 200 meters from them.
3. The authorizations referred to in paragraphs 1 and 2 specify suitable measures to reduce the risk of ignition and the spread of fire in the surrounding areas.

    - Include information on the scope of these regulations, including the types of critical infrastructure covered, the specific preventive measures required, and the responsible authorities for enforcement.

The public bodies competent for the management of road (municipalities, provinces, regions may stipulate agreements with the owners or in any case holders of the adjacent and contiguous areas for the purposes of management and maintenance of the relevant area.
Electric power operators are in charge of cleaning areas around high voltage power network.
Train operator (e.g. Tranitalia) are in charge of cleaning the area around railways.

- Describe the mechanisms for enforcing these regulations, including any penalties or sanctions for non-compliance.

LEGGE 21 novembre 2000 , n. 353: Legge-quadro in materia di incendi boschivi.
Art. 3. Piano regionale di previsione, prevenzione e lotta attiva contro gli incendi boschivi

In the event of **non-compliance** by the regions, the Minister delegated for the coordination of civil protection, using the Civil Protection Department, the National Fire Brigade and the State Forestry Corps, having consulted the Unified conference, prepares, also at an inter-provincial level, emergency activities for extinguishing forest fires, taking into account the operational structures of the provinces, municipalities and mountain communities.

- Effectiveness and Challenges:
  - Assess the effectiveness of the current laws and regulations in preventing forest fires caused by critical infrastructure.

Apparently, current laws and regulations do not include penalties in case of non-compliance with the requirements.

  - Identify any challenges or gaps in the existing legislative framework, such as insufficient coverage of critical infrastructure types, unclear requirements, or inadequate enforcement mechanisms.

Then, among challenges and/or gaps we can mention:
- inadequate enforcement mechanisms;
- insufficient monitoring of the implementation of the prescriptions;

- Gap Analysis:
  - Based on the information provided, identify any gaps or areas for improvement in the national legislation and regulations related to forest fire prevention and critical infrastructure.

Based on the previous information the area of improvement includes:

- The introduction of a mechanism of monitoring of the compliance of the prescriptions, based even on satellite images, concerning the cleaning of the band around the infrastructure.

- Suggest potential amendments or new regulations that could enhance the effectiveness of forest fire prevention efforts.

For new installations of critical infrastructures, evaluating their locations by considering potential wildfire hazard (e.g.: by fire spread modeling or considering historical events) and vulnerability of the area.
Promoting the building of firebreaks and fuelbreaks for both a more effective control of wildfire spread and behavior and to have safe areas and anchor points from which suppression operations can be carried out safely.
Better care should be taken in planning and maintaining the local road network, as well as in creating databases that can inform fire managers about the potential or limitations of given roads for terrestrial forces (e.g.: trucks cannot be used in specific roads).
For some infrastructures (e.g.: wind farms), the operational potential of aerial firefighting forces is largely limited for safety reasons; under these conditions, to carry out ground operations in safe conditions, appropriate road networks should be designed and guaranteed in the long term (e.g. avoiding narrow or closed roads or risk of entrapments).

Additional Comments

- Please provide any additional comments or insights related to the intersection of critical infrastructure and forest fire risks in your country.

- Share any best practices or successful initiatives that have been implemented to mitigate the fire risk associated with critical infrastructure.

- Suggest areas for further research or collaboration to improve forest fire prevention and critical infrastructure safety.

Date: 16/0172024
Place: Rome

Fireurisk Consortium Questionnaire:

National Legislation on Forest Fire Prevention Linked to Critical Infrastructure

Respondent Information

- Country of Representation: Please specify your country:

GREECE

Data on Wildfires and Critical Infrastructure

- Annual Statistics on Wildfires Attributed to Critical Infrastructure:
  - Please provide the number of wildfires in your country over the past year that were attributed to critical infrastructure.

According to data published by the Forst Resaerch Institute for the period 1983-2006 and focusing on the causes related to "Σπινθήρας μηχανής" (Sparks from machines) and "Βραχυκύκλωμα" (Short circuit), we can make some relevant conclusions:

- Sparks from Machines ("Σπινθήρας μηχανής"): Percentage of Burned Area: 1.0%, Percentage of Events: 0.4%. This cause accounts for a relatively small percentage of the total number of events and the burned area. These instances are likely related to equipment use, potentially including power tools, vehicles, and other machinery that can emit sparks and ignite fires.
- Short Circuit ("Βραχυκύκλωμα"): Percentage of Burned Area: 4.2%, Percentage of Events: 2.2%. Short circuits are a more significant cause of wildfires in terms of the number of events and the burned area. This cause is directly related to electrical failures, which could include issues with power grid infrastructure such as power lines, transformers, and associated equipment operated by energy companies like ΔΕΗ. Given the nature of these incidents, they are likely a result of equipment malfunction, maintenance issues, or external factors affecting the power grid.

Short circuits, thus, not only occurred more frequently but also resulted in larger fires on average, suggesting that incidents involving the power grid infrastructure had a more significant impact on wildfire outbreaks in terms of both frequency and severity. In contrast, sparks from machines were less frequent and had a smaller average size, indicating that while they were a risk factor, they played a less dominant role in the context of wildfire causes during the period from 1983 to 2006 in Greece.
Source: http://www.oikoskopio.gr/pyroskopio/pdfs/pyrkagies-ellada.pdf

  - If available, include a brief summary of the trends observed over the last five years.

Based on data from fires that have been reported and linked to power grid/spark as cause it can be deduced an increase in burned areas and number of incidents the last decade. Data showing this trend are briefly presented here next:

1993 (24/7/1993) – Lasithi, Crete: Burnt area was 25,000 hectares. The cause was attributed to negligence, with indications pointing towards ΔΕΗ. The fire was extinguished after three days.
2007 (27/6/2007) - Voiotia / Stefani-Dervenohoria-Parnitha: Burnt area was 50,450 hectares, of which 27,200 hectares affected the Parnitha region. The cause was attributed to negligence, with indications pointing towards ΔΕΗ.
2014 (26/6/2014) – Fthitida/Mazi-Malesina: Burnt area was 25,830 hectares. The cause was attributed to negligence, with indications pointing towards ΔΕΗ.
2015 (17/7/2015) – Lakonia/Neapoli (Falakro): Burnt area was 43,250 hectares. The cause was negligence by ΔΕΗ, leading to the conviction of three ΔΕΗ officials in the first degree.
2016 (23/7/2016) – Chios/Elata (Mastichochoria): Burnt area was 52,420 hectares. The cause was attributed to negligence, with indications pointing towards ΔΕΗ.
2017 (1/7/2017) – Lakonia/Mani (Pyrichos): Burnt area was 24,693 hectares. The cause was attributed to negligence, with indications pointing towards ΔΕΗ.

These cases emphasize the significant consequences of negligence and lack of maintenance in critical infrastructure, particularly in the energy sector, and the importance of ensuring that these infrastructures are adequately managed to prevent environmental disaster
Source: Gourbatsis A. Fatal and destryctive forest fires in Greece (1980-2020. Investigation report. https://tinyurl.com/yh7hmfqq

- Critical Infrastructure Contributing to Fire Ignitions:
    - Identify the types of critical infrastructure in your country that have most frequently been associated with the ignition of wildfires. Examples include power lines, transportation networks, industrial complexes, etc.

For the period 1984-2009 (24 years), according to the data of the PYROSTAT database of the Laboratory of Material and Forest Fires of the Aristotle University of Thessaloniki (Figure P-1), the causes of forest and countryside fires are distributed throughout Greece as follows: negligence (11.26%), arson (11.49%), unknown causes (57.24%), field burning (8.25%), pasture creation (7.67%) and natural causes (4.09%) (Figure 5). Correspondingly, the percentages of total burned areas depending on the cause of fires are distributed throughout Greece as follows: negligence (18%), arson (12.93%), unknown causes (51.65%), field burning (8.87%), creation of pastures (7.50%) and natural causes (1.05%).
Some causes can be prevented by technological improvements in the means and practices used which often cause fires. Examples are catalytic converters in cars, spark traps in internal combustion engines, brake materials for railway trains, materials for power grids and their maintenance in good condition, smokers used by beekeepers for smoking bees, Both technological development and the promotion of improved solutions in practice are important elements of prevention. (https://www.government.gov.gr/report-on-landscape-fires-in-greece/)

    - Provide any available data or case studies that illustrate these links.

Maintenance shortcomings in Greece's power grid, spanning approximately 250,000 kilometers and overseen by ADMIE and HEDNO, have been implicated in the ignition of wildfires. Deficient control of power pylons and lines, such as those managed by the Public Power Corporation (DEI), are linked to significant forest blazes, including those in Kapandriti and Eastern Mani, destroying around 60,000 hectares. Despite a substantial maintenance budget, potentially over 40 million euros annually, the extent of program execution is unclear. Inadequate tree trimming near power lines and insufficient cleaning of electrical components are key issues, potentially causing sparks and wildfires. It's estimated that 2%-3% of fires may be related to DEI's network, but the figure could be higher, as the origins of 40% of forest fires are unknown. There have been instances where the electrical network was deemed responsible for fires, leading to legal actions against DEI officials. ADMIE and HEDNO assert continuous, structured maintenance efforts, including the use of helicopters and specific clean-up operations. Measures are taken to prevent forest fires by clearing vegetation around power lines and maintaining equipment, especially in areas susceptible to environmental wear. Source: https://www.tovima.gr/2017/08/25/society/oi-ablepsies-tis-dei-poy-bazoyn-fwtia-sta-dasi/

National Legislation and Regulations

Article 32 of Greek Law 5075/2023 stipulates measures for clearing and creating firebreak zones within the servitude areas of power transmission lines of the Greek Electric Power Transmission System, adding Article 53B to Law 4662/2020. This provision allows, in a limited scope, cleaning, tree pruning, clearing, tree cutting, removal of these and residues from logging, and cleaning operations at the base of towers within servitude zones. This is to establish a safe firebreak zone, which is 15 meters on each side of the axis of 150 kV lines and 20 meters for 400 kV lines that pass through forests or forested areas.
The works are carried out by the Independent Power Transmission Operator (ADMIE) at its expense, following guidance from the competent organs of the Fire Service for creating firebreaks in specific locations. Execution of these works requires permission from the responsible forestry service and private landowners, if applicable.

ADMIE must submit a request for the relevant permit, which is issued within 15 days of application. If the deadline is missed, the permit is deemed granted, allowing ADMIE to proceed with the necessary works with simple notification to the competent forestry authorities.
The products of logging are delivered either to the responsible forest service if they come from public forests and lands, to be allocated according to existing legislation, or to private forest owners if they come from private lands. If the interventions mentioned cause harm to the usual exploitation of private lands, compensation may be granted in accordance with the provisions of the existing laws.
Additionally, the Hellenic Electricity Distribution Network Operator (HEDNO) may carry out similar cleaning and tree pruning to create safe firebreak zones around medium voltage components within three meters on each side, extendable to 15 meters in exceptional cases due to land morphology. These operations are carried out by HEDNO at its expense and require a permit from the competent forestry service and private landowners if it concerns private lands.
A joint decision by the Ministers of Climate Crisis and Civil Protection and of Environment and Energy may regulate any relevant issue related to the above, particularly the procedure and the competent bodies of the Fire Service to indicate the necessary works. Source: https://dasarxeio.com/wp-content/uploads/2023/12/n_5075_2023.pdf

- Existing Laws and Regulations:

Describe the national laws or regulations in place aimed at preventing forest fires specifically related to critical infrastructure. Please provide the specific name or reference of each law or regulation. Include information on the scope of these regulations, including the types of critical infrastructure covered, the specific preventive measures required, and the responsible authorities for enforcement.

The Greek law N. 5075/2023 primarily focuses on restructuring civil protection, enhancing the effectiveness of the national mechanism for aerial search and rescue, and other urgent regulations for state aid. Regarding the prevention of forest fires in relation to critical infrastructure, the law addresses the following aspects:
Normative and Legislative Framework: The law includes provisions for preventive measures to protect against forest fires. These measures relate to different stages of disaster management, including prevention, preparedness, response, and short-term recovery.
Critical Infrastructure: The law provides for the clearance and creation of firebreak zones within the easement zones of electricity transmission lines belonging to the Greek Electricity Transmission System. This involves clearing vegetation, pruning trees, and other measures to ensure a safe fire protection zone around critical energy infrastructure.
Preventive Measures: Specific preventive actions are mandated, such as clearing vegetation and maintaining certain distances from high voltage power lines to reduce fire risks.
Responsible Authorities: Various authorities are tasked with enforcement, including the Independent Power Transmission Operator (ADMIE) and the Hellenic Electricity Distribution Network Operator (HEDNO), who are responsible for maintaining clearance around power lines and ensuring that protective measures are in place.
Compliance and Enforcement: The law also details the process of obtaining necessary permits from forestry services for conducting these preventive activities, and outlines the responsibilities of ADMIE and HEDNO in ensuring compliance with these regulations.
Collaborative Efforts: There is a coordinated approach involving the Fire Service and the Forestry Services to manage large-scale forest fires and implement preventive measures.
In summary, the law emphasizes an integrated approach to managing and reducing the risk of forest fires related to power infrastructure, assigning specific responsibilities to relevant authorities and detailing preventive measures that need to be taken.

In Greece, the legal framework aimed at preventing forest fires, especially in relation to critical infrastructure such as power lines, includes the following (https://civilprotection.gov.gr/sites/default/files/2023-04/Εγκριση%20και%20αποστολή%205ης%20έκδοσης%20Γενικού%20Σχεδίου%20Δασικών%20Πυρκαγιών%20-%20ΑΔΑ%20ΡΣΛΘ46ΝΠΙΘ-ΝΛ5.pdf) :

1. The Forest Law (Law 998/1979) which, although it allows for certain activities within forested areas, includes strict regulations and conditions to ensure the protection of forests from fire risks originating from power lines and other infrastructural works.
2. Law 4662/2020, particularly Article 53B, introduced specific provisions for the maintenance of safety zones along electricity transmission lines. This involves the clearance, pruning, and removal of trees and vegetation within a specified distance from the power lines to create firebreaks, ensuring that vegetation does not come into contact with power infrastructure and potentially ignite a fire.
3. In Greece, the national law regarding the prevention of forest fires specifically related to critical infrastructure, such as power lines, is included in the broader context of wildfire management policies. The key legislation is part of a comprehensive wildfire management plan known as "ΙΟΛΑΟΣ 2" (5th Edition 2022) which outlines a variety of strategies and actions to address forest fires. This includes the identification of fire risk areas, the role of critical infrastructure in fire prevention, and the mechanisms in place for managing and mitigating risks associated with wildfires.

The scope of these regulations covers high-voltage power lines with required clearances of 15 meters on each side for lines with a voltage of 150 kV, and 20 meters for lines with a voltage of 400 kV. The regulations apply to both public and private land, with mandatory compliance by the power transmission companies. These preventive measures are required to be executed with guidance from the Fire Service and after obtaining necessary permits from forest authorities.

Specific preventive measures mandated by these regulations involve maintaining clear zones around power lines, implementing vegetation management strategies to prevent contact with electrical infrastructure, and ensuring the readiness of power lines and related equipment to withstand fire-related risks. In the case of identified high-risk areas, there are additional measures such as increased surveillance and the use of advanced technologies to monitor the conditions around power lines.

The enforcement of these preventive strategies falls under the purview of various authorities, including but not limited to, the General Secretariat for Civil Protection (Γενική Γραμματεία Πολιτικής Προστασίας), the Hellenic Fire Service (Πυροσβεστική Υπηρεσία), and the organizations responsible for the maintenance and operation of the power grid infrastructure. These entities coordinate to ensure that the necessary preventive actions are taken and that emergency protocols are in place in the event of a wildfire.

This plan outlines a multi-tiered approach to managing forest fires, emphasizing a synergy between prevention, immediate response, and recovery efforts. Furthermore, it acknowledges the significance of collaboration between various agencies and stakeholders to effectively manage and mitigate the risks posed by wildfires to critical infrastructure and the environment

- Describe the mechanisms for enforcing these regulations, including any penalties or sanctions for non-compliance.

The law is applied under the auspices of the Greek Civil protection (General Secretariat) and the Hellenic Fire Service legal and administrative mechanism.

- Effectiveness and Challenges:
    - Assess the effectiveness of the current laws and regulations in preventing forest fires caused by critical infrastructure.

The law is quite recent and its effectiveness can't be assessed at this stage.

    - Identify any challenges or gaps in the existing legislative framework, such as insufficient coverage of critical infrastructure types, unclear requirements, or inadequate enforcement mechanisms.

The main gap is a codification of the legislation regarding forest fire related laws, regulations, decrees, directives etc that would facilitate the coordination, control and monitoring of the fire prevention activities by the all the rlevant and involved authorities and organizations.

- Gap Analysis:
    - Based on the information provided, identify any gaps or areas for improvement in the national legislation and regulations related to forest fire prevention and critical infrastructure.

Develop a well organized codification of the existing legislation defining actors, responsibilities, obligations and needs for cooperation and coordination between involved stakeholders.

    - Suggest potential amendments or new regulations that could enhance the effectiveness of forest fire prevention efforts.

Coordination between legislation concerning critical infrastructures, forest policies and civil protection policies in order to be compatible and complementary between them.

Additional Comments

- Please provide any additional comments or insights related to the intersection of critical infrastructure and forest fire risks in your country.

According to the Network Management Code (Official Gazette Issue B, 78/20.01.2017), the DEDDIE takes all necessary reasonable actions to ensure the good operation of the Network, under normal or emergency conditions. Compliance with European and National Regulations and the issuance of relevant instructions (Network Operation Manual, Internal Technical Instructions, etc.). Also, taking further measures to ensure the operation of the Network in extreme weather conditions and compliance with the General Plans of the General Secretariat of Civil Protection (for Fires, Floods and Snowfalls, Earthquakes, Volcanoes and Technological Accidents), which are issued in the framework of the "Xenocratis" General Plan. DEDDIE specifies these plans, issuing internal memos and instructions for taking measures. (https://deddie.gr/media/7847/schedio-anaptixis-dyktyou-2021_2025-network-development-plan-2021-2025.pdf)

- Share any best practices or successful initiatives that have been implemented to mitigate the fire risk associated with critical infrastructure.

- Suggest areas for further research or collaboration to improve forest fire prevention and critical infrastructure safety.

Date: 15/01/2014
Place: Athens

Fireurisk Consortium Questionnaire:

National Legislation on Forest Fire Prevention Linked to Critical Infrastructure

Respondent Information

- Country of Representation: Please specify your country: **Scotland, the UK**

Data on Wildfires and Critical Infrastructure

- Annual Statistics on Wildfires Attributed to Critical Infrastructure:
  - Please provide the number of wildfires in your country over the past year that were attributed to critical infrastructure.

There were severe fires, in 2023, when one blaze is estimated to have burned the second-largest amount of area on record. **2023 saw the hottest June on record in Scotland with multiple wildfire incidents reported. The wildfire in Cannich, near Inverness, burned for almost 2 weeks with devastating consequences** for wildlife and humans (with evacuations, property damage, etc.). The destruction of critical infrastructure, including roads and utilities, further exacerbates the consequences of fires for local communities.

  - If available, include a brief summary of the trends observed over the last five years.

In the last 5 years, the most fires recorded in Scotland were in 2019, with 38. Fires on *heathlands/shrublands accounted for up to 50%.* From 2001 to 2022, Scottish Highland had the highest rate of tree cover loss due to fires with an average of 200 ha lost per year.

- Critical Infrastructure Contributing to Fire Ignitions:
  - Identify the types of critical infrastructure in your country that have most frequently been associated with the ignition of wildfires. Examples include power lines, transportation networks, industrial complexes, etc.

Nearly all UK wildfire ignitions are anthropogenic. It is considered that most wildfires in Scotland are caused by people: accidentally - e.g. campfires, BBQs, cigarettes, etc. and by 'managed' burns, when fire is used as a management tool and is part of grazing and hunting practices, much of which occurs in uplands and moorlands.

  - Provide any available data or case studies that illustrate these links.

I am not aware of publicly available data on a significant contribution of Critical Infrastructure to wildfire ignition in Scotland. However, offshore oil and gas platforms, the Grangemouth oil Refinery and petrochemical plant, military communication facilities of Kinloss Barracks and Crimond in north east *Scotland,* power stations (including one nuclear station in operation), electricity and gas sub-stations, mobile phone networks, critical engineering facilities, numerous pipelines, especially onshore pipelines and terminals that connect the north east of Scotland to its industrial central belt (this allows some of this infrastructure to be used for clean hydrogen and CO_2 transport, while the rest is used for natural gas, as Scotland migrate away from fossil fuels), in the event of their downtime/shutdown or accidental situations can be associated with the ignition of wildfires. These require F*ire & Risk Management, including monitoring and* fire prevention and protection. Accidents related to numerous offshore pipelines (between hydrocarbon fields and the shore, and between fields) can hardly cause forest fires.

National Legislation and Regulations

Existing Laws and Regulations:

- Describe the national laws or regulations in place aimed at preventing forest fires specifically related to critical infrastructure. Please provide the specific name or reference of each law or regulatio

In March 2011, the Scottish Government published its first ever strategy for Critical Infrastructure Resilience (CIR) in Scotland – 'Secure and Resilient – A Strategic Framework for Critical National Infrastructure in Scotland.' The Fire and Rescue Framework for Scotland 2016 and the next, of 2022 (following public consultation), set out priorities and objectives for the Scottish Fire and Rescue Service (SFRS). SFRS has have a statutory duty, under the Fire Scotland Act (2005), The Fire (Additional Function) (Scotland) Order (2005) and others. The other regulations and those, specifically concerning the land use sector (important for Scotland) and on wildfires include: Fire and Rescue Service Wildfire Operational Guidance, 2013; Wildfire prevention, the Scottish Forestry which advises that managers should plan for forest resilience whilst considering the risk from fire. There are also relevant regulations at the UK level e.g., the UK Forestry Standard. Guidance is provided in the UK Forestry Commission (2014) Practice Guide 22: Building Wildfire Resilience into Forest Management Planning and in the FC regulation on wildfire prevention. The Information Note supports forest owners, planners, and managers in Scotland to implement this guidance. The wildfire prevention by the Forestry and Land Scotland is executed in collaboratively with the Scottish Fire and Rescue Service and the Scottish Wildfire Forum. The Wildfire Strategy of Scottish Fire and Rescue Service, their Guidance, 2023 and leaflets are important in preventing forest fires. Also, Preventing Wildfires on Agricultural Land document offers practical strategies and downloadable tools to help take steps to reduce the risk of wildfires. For example, controlled burns in compliance with the Muirburn Code **and** under Fire and Rescue Service expert supervision can be an effective tool.

- Include information on the scope of these regulations, including the types of critical infrastructure covered, the specific preventive measures required, and the responsible authorities for enforcement.

- Describe the mechanisms for enforcing these regulations, including any penalties or sanctions for non-compliance.

The Building Scotland (Amendment) Regulations 2022 and standards on fire safety came into force on 1 June 2022. In October, 2023, new fire safety guidelines were put in force for all buildings regulated by the Regulatory Reform (Fire Safety) Order 2005. The new regulations aim to enhance collaboration and coordination between responsible persons, impose stricter requirements for recording and sharing of fire safety information, simplify the process for enforcement authorities to take action against non-compliance. Fire safety guidance for existing non-residential premises (2022) provides advice for duty holders of premises including commercial, industrial, transport, educational (also belonging to critical infrastructure). Guidance on carrying out a fire safety risk assessment of non-domestic premises have come to power and new fire safety requirements (2023), while the Fire Safety Reform Programme entered its third phase in October 2023. One of the most significant implications is that regulators will now have greater power to ensure adherence to fire safety standards. A new Building Safety Regulator, with powers to enforce penalties ranging from fines to prison sentences against those who fail to comply with the regulations. The Regulatory Fire and Safety Order is enforced by the Fire and Rescue Service, local authority environment departments or Environmental Health. Details on sanctions and penalties are unknown to me.

- Effectiveness and Challenges:
- Assess the effectiveness of the current laws and regulations in preventing forest fires caused by critical infrastructure.

The Critical National Infrastructure (CNI) fire safety approach is in use and the sector has excellent global reputation as they constantly use innovative technology and science to keep all, as safe as possible. However, if the hazard is special and the infrastructure critical, there is a case for the constant monitoring of the fire suppression systems that aim to deliver the protection (Hunter, 2022). Inspection should also include an evaluation that the extinguishing system continues to provide adequate protection for the risk. In CNI, in Scotland, the technical means and capabilities for doing it exist, but a challenge is to fully utilise these and advance further the technology, including digital/AI (subject to regulations, financial and other constraints that may come up).

- Identify any challenges or gaps in the existing legislative framework, such as insufficient coverage of critical infrastructure types, unclear requirements, or inadequate enforcement mechanisms.

Somewhat more attention could be given to human factor (social capital, the role of social innovation, etc.), as it is very important for implementing fire prevention measures, while in Scotland, most wildfires are currently caused by people, and classified either as accidental or as arising from the use of fire as a tool to enhance grazing and hunting.

Apparently, climate change will necessitate a refinement of the regulation, especially in Scotland, where land use and forestry are important sectors. Apparently, in future, the causes of fires will be different and associated with the changing climate, warmer summers, and natural disturbances and extreme events, it will bring.

- Gap Analysis:
  - Based on the information provided, identify any gaps or areas for improvement in the national legislation and regulations related to forest fire prevention and critical infrastructure.

In Scotland, offshore oil and gas platforms, the oil refinery and petrochemical plant, power stations and numerous pipelines are objects of critical infrastructure that need special attention. Scotland does not routinely investigate the cause of wildfire ignitions and has no fire investigators qualified in this specialist skill.

  - Suggest potential amendments or new regulations that could enhance the effectiveness of forest fire prevention efforts.

Currently, the UK private sector constitutes 96% of all expenditure on tackling fires. More is to be done in the public sector, including financial allocations to enhance the effectiveness of forest fire prevention efforts, and concerning multi-level governance (e.g. by promoting public-private partnerships, encouraging social innovation, etc.). Capacity building, social learning and exchanging of best practices and lessons learned are to be promoted (using various policy/governance instruments, including regulative.

Additional Comments

- Please provide any additional comments or insights related to the intersection of critical infrastructure and forest fire risks in your country.

There are two distinct wildfire regimes in Scotland; those that occur in woodland habitats, which are frequent but with low burned area, and those in open habitats (e.g. moorland) that tend to account for the largest burned areas. In addition, a large number of wildfires occurs in built-up areas and gardens. Although these account for a low average burned area they pose a significant risk to life, properties, and critical infrastructure. To my knowledge, there is not much of the intersection of critical infrastructure and forest fire risks in my country.

- Share any best practices or successful initiatives that have been implemented to mitigate the fire risk associated with critical infrastructure.

I am not aware of examples, as currently, the fire risks in Scotland are not directly and noticeably associated with critical infrastructure.

- Suggest areas for further research or collaboration to improve forest fire prevention and critical infrastructure safety.

With the changing climate, fires will increase in their numbers, scales, and consequences. This is to be accounted for, more. The role of social innovation and third sector to improve forest fire prevention is to be explored and utilised, more.

Maria Nijnik

Date: 18/01/2024, Place: Aberdeen, Scotland

Fireurisk Consortium Questionnaire:

National Legislation on Forest Fire Prevention Linked to Critical Infrastructure

Respondent Information

- Country of Representation: Please specify your country:

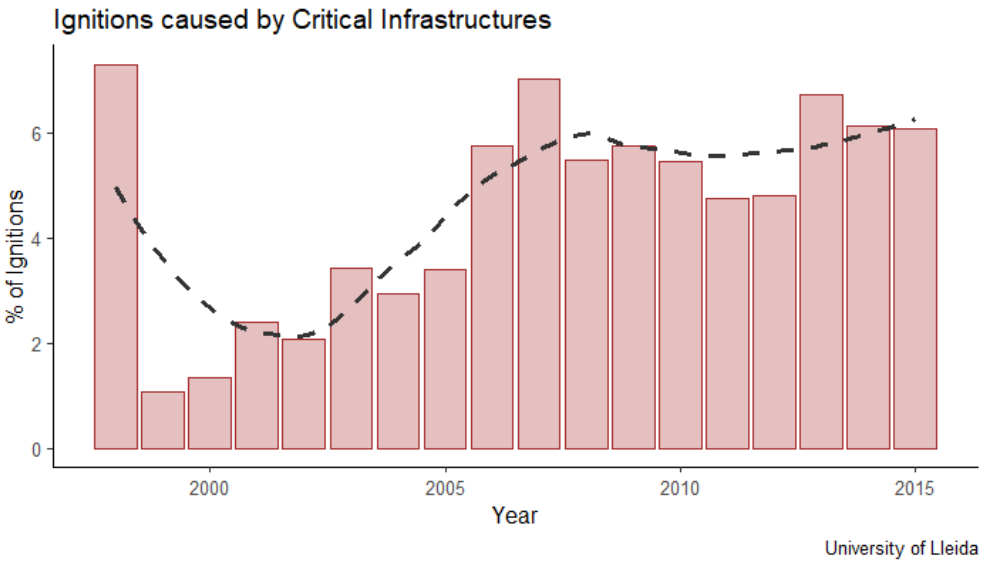
SPAIN

Data on Wildfires and Critical Infrastructure

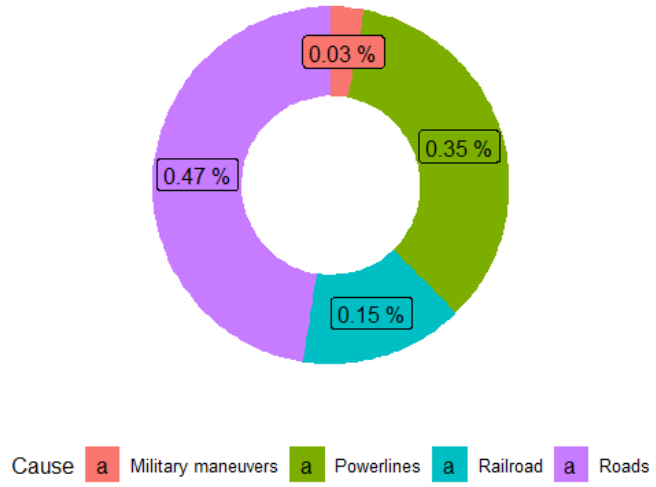
- Annual Statistics on Wildfires Attributed to Critical Infrastructure:
  - Please provide the number of wildfires in your country over the past year that were attributed to critical infrastructure.

16655 Ignitions (2.89 %) (1998-2015). The EGIF database has been temporally suspended and we have no data after 2016.

  - If available, include a brief summary of the trends observed over the last five years.



- Critical Infrastructure Contributing to Fire Ignitions:
  - Identify the types of critical infrastructure in your country that have most frequently been associated with the ignition of wildfires. Examples include power lines, transportation networks, industrial complexes, etc.



- Provide any available data or case studies that illustrate these links.

https://www.miteco.gob.es/es/biodiversidad/temas/inventarios-nacionales/inventario-espanol-patrimonio-natural-biodiv/sistema-indicadores/06c-estadistica-incendios-forestales.html

Campañas (miteco.gob.es)

Campañas en medios de comunicación (miteco.gob.es)

Efectos negativos sobre el PNB. Letra I (miteco.gob.es)
miteco-librolosincendiosenrednatura-pdfdigital2022_tcm30-550138.pdf

National Legislation and Regulations

- Existing Laws and Regulations:

All relevant laws and regulations can be found in:
https://www.mapa.gob.es/en/desarrollo-rural/legislacion/leg-espanola-forestal-incendios.aspx

BOE-A-1973-208 Decreto 3769/1972, de 23 de diciembre, por el que se aprueba el Reglamento de la Ley 81/1968, de 5 de diciembre, sobre Incendios Forestales.

- Describe the national laws or regulations in place aimed at preventing forest fires specifically related to critical infrastructure. Please provide the specific name or reference of each law or regulation.

- Include information on the scope of these regulations, including the types of critical infrastructure covered, the specific preventive measures required, and the responsible authorities for enforcement.

Forest laws are the competence of Autonomous Communities, 17 in Spain, as political units that jointly form the State, Spain. That makes for relevant differences in the way forest fires and management are organized, and regulations for infraestructures in terms of fire prevention.

General provisions on wildland fires: Ley 43/2003, de 21 de noviembre, de Montes
https://www.boe.es/buscar/pdf/2003/BOE-A-2003-21339-consolidado.pdf
The Autonomous Communities will regulate in forest and nearby areas all activities that can rise fire risk and will establish safety regulations aplicable to buildings, operations, power instalations and transportation networks in forest areas and their surroundings, when these activities can increase fire risk, or be affected by fires.

Ley 7/1985, de 2 de abril, Reguladora de las Bases del Régimen Local assigns rights (competences) to townships for prevention and suppression.
https://www.boe.es/buscar/act.php?id=BOE-A-1985-5392

Real Decreto-ley 15/2022, de 1 de agosto, was devoted to urgent measures in forest fires matters.
https://www.boe.es/buscar/act.php?id=BOE-A-2022-12926

An exemple of criteria for the design and maintenance of forest roads as fire prevention infrastructures in CCAA Valencia can be found in:
https://cjusticia.gva.es/documents/162905929/163206728/NT+Viales+forestales+%289%2C7Mb%29/5996f665-3fd2-46ed-a8e6-99f5e953576f

An example in Catalonia can be found here:
DECRETO 130/1998, de 12 de mayo, by which measures of fire prevention are established in areas of influence of roads.
http://www.carreteros.org/ccaa/legislacion/carreteras/cataluna/otras/d130_1998
.pdf

Actions (vegetation clearance) under power lines by the State Power Company (CEE) are described here:
https://www.ree.es/en/sustainability/the-natural-environment/fire-prevention/gallery-fire-prevention

The above-mentioned laws and regulations describe preventive measures, actions and sanctions on roads and power lines. In general terms, vegetation clearance is required at set distances from roads according to their order of importance, or under power lines depending on risk of tree falling, there are safety corridors and obligatory clearance distances.
For train infrastructure, the situation is similar (there are corridors and regulations to treat the herbaceous vegetation on the corridor), but older local lines (the whole secondary network, not the primary high-speed network) have suffered from lack of maintenance due to financial cuts in budgets and personnel. No adequate maintenance of the stopping devices and of the rail is being performed. No consequences are apparent, nor enforcement is in place. Many stations are closed and abandoned.

    - Describe the mechanisms for enforcing these regulations, including any penalties or sanctions for non-compliance.

- Effectiveness and Challenges:
    - Assess the effectiveness of the current laws and regulations in preventing forest fires caused by critical infrastructure.

Ignition trends seem stable, but they are not decreasing as they should in application of the measures, since many are lacking. Control of vegetation along thousands of kms of power lines, railways and roads is complicated, and procedures are not effective when vegetation growth rates are not considered by depleted public services. Many operations belong to private power or railway companies, and they do not invest in prevention.

    - Identify any challenges or gaps in the existing legislative framework, such as insufficient coverage of critical infrastructure types, unclear requirements, or inadequate enforcement mechanisms.

Dispersion of designs and regulations across 17 CCAAs, lack of funding and personnel. Lack of directives to private companies.

- Gap Analysis:
    - Based on the information provided, identify any gaps or areas for improvement in the national legislation and regulations related to forest fire prevention and critical infrastructure.

-Coordination between CCAAs in technical specifications, mainly for roads, railways and power lines.
-Enforce more funding from private companies in adequate maintenance of their transportation networks.
-Nobody pays for the damages caused.
-There are not courts of law demands against the causing people. No demands from insurance companies who only seek to settle funds to satisfy their clients for damages.
-Colateral damages are not valued/estimated and few receive subsidies.
-In Spain very few judicial processes tackle negligence from agriculture, civil society, forestry, harvesting or uses of the forest when they produce a large fire.
-There are not robust plans for educating or informing society on large fires, or a fire culture that makes people understand that sometimes fire is out of suppression capacity, and will keep burning areas.
-Little awareness that some scenarios lead to imposible situations for extinction, that will cause irreparable damage.

- Suggest potential amendments or new regulations that could enhance the effectiveness of forest fire prevention efforts.

Joint CCAA technical especifications and regulations for supervision/monitoring of vegetation conditions based on new RS sources, available lidar data, for instance. Regulations should be enforced thru fines or administrative action.

Additional Comments

- Please provide any additional comments or insights related to the intersection of critical infrastructure and forest fire risks in your country.

Infrastructures cause fires due to lack of adequate maintenance. Budgets and personnel are lacking in public companies. Private companies tend to not invest if not enforced.

- Share any best practices or successful initiatives that have been implemented to mitigate the fire risk associated with critical infrastructure.

There is an anual Plan for fire prevention in RENFE (now ADIF), they added in 2005 an Extraordinary Plan for fire prevention in the line and surrounding terrain. It was a good inittiative, but did not work for lack of funding. Sometimes trafic is interrupted because of fire risk.

Suggest areas for further research or collaboration to improve forest fire prevention and critical infrastructure safety.

Spatial optimization of maintenance work locations based on environmental/vegetation conditions under limited funding.

Date: 17/4/2024
Place: Lleida