

FIREPRIME

Guideline for Wildfire Risk Assessment

Infrastructure Type: Electrical Substations

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The FIREPRIME Project - Introduction

FIREPRIME is a research project funded by the European Union Civil Protection Mechanism. FIREPRIME seeks to lay the foundations of a European program that promotes wildfire risk culture and resilience among communities, with a civil protection perspective. FIREPRIME is developed in three different regions of the EU, in close collaboration with local authorities and communities. A set of risk awareness and assessment tools, named as FIREPRIME Toolkit, have been designed and adapted to the EU context through three streams: homeowner fire safety, community engagement and resilient infrastructures. This document provides the guidelines and background information for filling in the risk assessment created for electrical substations, as part of the FIREPRIME infrastructure stream.

1. Background:

Wildfires and critical infrastructure impact – Electrical Infrastructure

Wildfires are a growing hazard worldwide, also due to the impact of climate change. The current European yearly critical infrastructure damage is €3.4 billion, this value is predicted to increase by over 10 times only due to climate change effects by the end of the century (Forzieri et al., 2018). Wildfire risk to critical infrastructure in Europe has been identified as an emerging issue needing intersectoral attention (Kern and Krausmann, 2020).

A recent analysis of over 450 power grid transmission blackout events across Europe, found that weather events were responsible for over 32% blackouts. Wildfires and the power grid have had significant interactions: power grid infrastructure has been recorded as causing and interacting with a number of destructive wildfires in the USA, Portugal and Australia, resulting in significant negative public perception impacts, physical damage, and operational disturbances (Mitchell, 2009; Victoria State Government, 2011; Ganteaume et al., 2021).

The FIREPRIME wildfire risk assessment presented in this document is an adaptation of the FIRESMART Wildfire Risk Assessment for Oil and Gas Installations available in Canada (Sustainable and Development, 2012). In the European Union, the CER Directive (EU 2022/2557) requires critical infrastructure operators to identify and assess all relevant risks—including natural hazards—and to implement appropriate resilience measures, including risk assessments, continuity planning, and incident reporting, to ensure the continued delivery of essential services (European Parliament and Council of the European Union, 2022). The FIREPRIME wildfire risk assessment guidelines are designed to provide an preliminary, qualitative resource to support the risk assessment and reduction from wildfire hazards.

The risk assessment explained in this guide is intended for safety managers, safety officers, or personnel responsible for safeguarding infrastructure against risks, especially natural hazards. It provides guidance for assessing potential wildfire risk, improving preparedness, and implementing effective mitigation measures.

Objectives of this risk assessment:

- Increase the wildfire risk awareness of industrial safety managers, including the awareness of most important wildfire behaviour and ignition influencing factors.
- Provide relative indicators of current wildfire risk level for the infrastructure.
- Provide general recommendations to implement effective wildfire risk mitigation measures.
- Advise if more rigorous assessment and quantitative risk assessments are necessary.

1.1 Introduction to Wildfire Exposure

Wildfires can impact or damage infrastructure and properties via four different wildfire exposure mechanisms:

- **Radiant heat:** Intense wildfire flames have been observed to impact different target infrastructure as far as 30 m away through radiant heat.
- **Direct flame contact:** occurs when burning fuel is located near enough to facilitate direct ignition of a target combustible.
- **Firebrands:** wind-transported burning fragments of vegetation or other fuel which ignite secondary fires upon landing or entering target infrastructure.
- **Fire environment:** Wildfire smoke, high winds and ambient temperatures.

Once a wildfire is ignited, the most important influencing factors affecting the intensity of the different wildfire exposures include:

- **Fuel type and condition:** Depending on the type of vegetation or man-made materials burning, their spatial conditions (how closely together they are spaced), and their conditions (for vegetation the fuel moisture content, determined previous weather conditions, strongly influences the burning behaviour)
- **The surrounding topography:** Flames spread faster and more intensely uphill. The relative location of the target of interest and its relation to the topography are therefore relevant to the speed and intensity of potential wildfire flames.
- **The wind speed and direction:** Wind strongly influences the wildfire rate of spread, and the ability and intensity of firebrand exposure.
- **The distance between flames to the target:** the distance between target infrastructure and possible burning fuel has been successfully used to estimate and reduce wildfire impact risk.

1.2 Power Grid Vulnerabilities

The following tables briefly summarise the recorded damage modes and wildfire ignition modes.

Table 1: Damage from Wildfire to the Power Grid

Damage to Power Grid	Damage pathways due to wildfire exposure
Conductor Impact	<ul style="list-style-type: none"> Heat transfer from flames increase conductor surface temperature Can result in conductor sag and reduced safety vertical clearance In extreme cases: Irreversible conductor annealing and loss of tensile strength Influences optimal power flow of the network and entire operation
Transmission Network Impact	<ul style="list-style-type: none"> Flames can damage transmission towers, and poles (especially wooden poles) Transmission lines can collapse Transmission capacity of line can be affected by heat, smoke, and particulate matter High temperature exposure can impact lifetime of transformers, battery units, and generation units
Transformers Leakage Current	<ul style="list-style-type: none"> Soot accumulation on insulators (due to wildfire smoke) can create conductive path that increases the potential for leakage current (LC): electricity, especially at higher voltages, jumps across an air gap to create a conductive path. LC occur between lines or from wires to the ground.

Table 2: Wildfire ignition causes by the Power Grid

General faults	Specific faults igniting wildfires
External environment - initiated	<ul style="list-style-type: none"> Trees, tree branches, birds, animals or vegetation making contact with powerlines - Causes improper electricity flow and generates sparks Conductor slap: Wind causing powerlines to clash, generate molten particles or make contact with objects Lightning striking powerlines Heat causing powerlines to sag and touch external object below
Power Grid faults	<ul style="list-style-type: none"> Downed Lines: Downed power lines remain “energized” as they fall and come to contact with vegetation Electric arcs: Ignites vegetation as the transmission line falls Extraordinary faults: <ul style="list-style-type: none"> Transformer explosions Poles collapse Fallen conductors

2. Risk Assessment Procedure and Scoring

2.1 Summary Overview of Assessment and Procedure

The risk assessment at hand is made up of two different sections that relate to the:

- **Wildfire Hazard:** The likelihood and intensity of the potential wildfire hazard threatening the infrastructure
- **Wildfire Impact:** The factors influencing the severity of the impact if the wildfire reaches and interacts with the infrastructure

The assessment includes questions separated in blocks related to specific areas of the infrastructure considered – there are a total of four blocks that are described in *Section 2.2 Risk Zones Definition*. Two blocks relate to the wildfire Hazard rating, and two blocks to the wildfire impact rating. Guidance to answer each question is provided in *Section 2.3 The Risk Assessment Procedure*. The answers to the questions provide two final scores, that are automatically calculated in the excel file. One relates to the wildfire hazard, and the other to the wildfire impact which are combined in a risk matrix to provide one overall score. Recommendations related to each block of the risk assessment are provided in *Section 3 Risk-Reduction Recommendations*.

SUMMARISED INSTRUCTIONS OVERVIEW:

- 1. Download and open the Wildfire Risk Assessment file in .xlsm format.**
- 2. Obtain relevant information regarding your infrastructure plant and immediate surroundings:** In section *2.3 Risk assessment procedure*, right after each step, there is list of the information and material needed to complete the related risk assessment section.
- 3. Divide Zone 3, Zone 2, and Zone 1 around your infrastructure, and count the number of building and external storage areas in your infrastructure to consider for Zone 1.** Refer to *section 2.2 Risk Zones definition* for guidance on how to do this.
- 4. Select risk description and individual score for each question:** For each influencing factor you have three options – which describe a low-risk scenario (score of 0) a medium risk (score of 1) and a high risk (score of 2). Select the most appropriate score for each question.
- 5. See your final score in the ‘Scoring Sheet’ and read the related recommendations.**

2.2 Risk Zones Definition

The risk assessment procedure assesses the most important hazards and vulnerabilities within and surrounding the industrial site. The assessment includes three wildfire-risk spatial zones, as illustrated in Figure 1, and an impact section. These main sections are described below.

The Wildfire Hazard: Zone 3 and Zone 2

- **Zone 3: > 50 meters** from infrastructure perimeter, up to 1 km. Considers the extended environmental surroundings and wildfire ignition history. This zone is significant in determining general likelihood of wildfire occurrence and intensity. This zone questions include a general assessment of local wildfire risk.
- **Zone 2: 10 – 50 meters** from infrastructure perimeter. The adjacent environment influences the likelihood of infrastructure being impacted by the wildfire front directly (via radiant heat) and indirectly (via firebrand exposure), and the speed at which the wildfire can reach the infrastructure.

Both zone 3 and zone 2 are assessed by dividing the considered areas into four quadrants and completing assessment questions for each quadrant (Refer to Figure 1 and Figure 2 for illustrations).

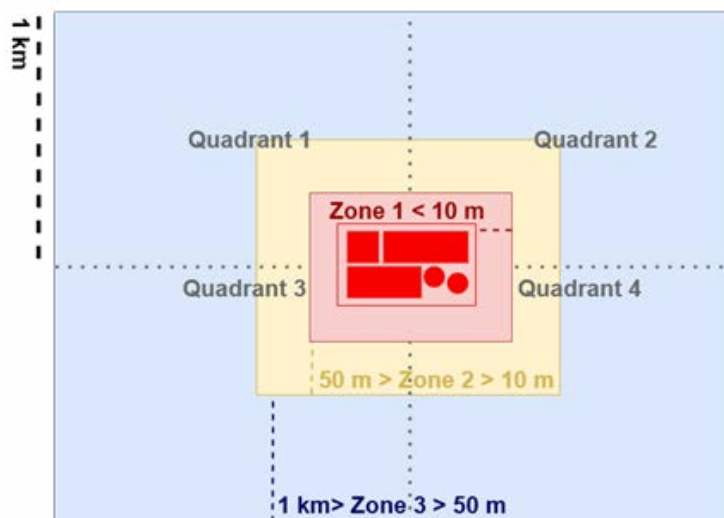


Figure 1: Schematic diagram illustrating relative zones for assessment – adapted from (FIRESMART, 2012). The red line within Zone 1 is meant to represent the industrial perimeter.

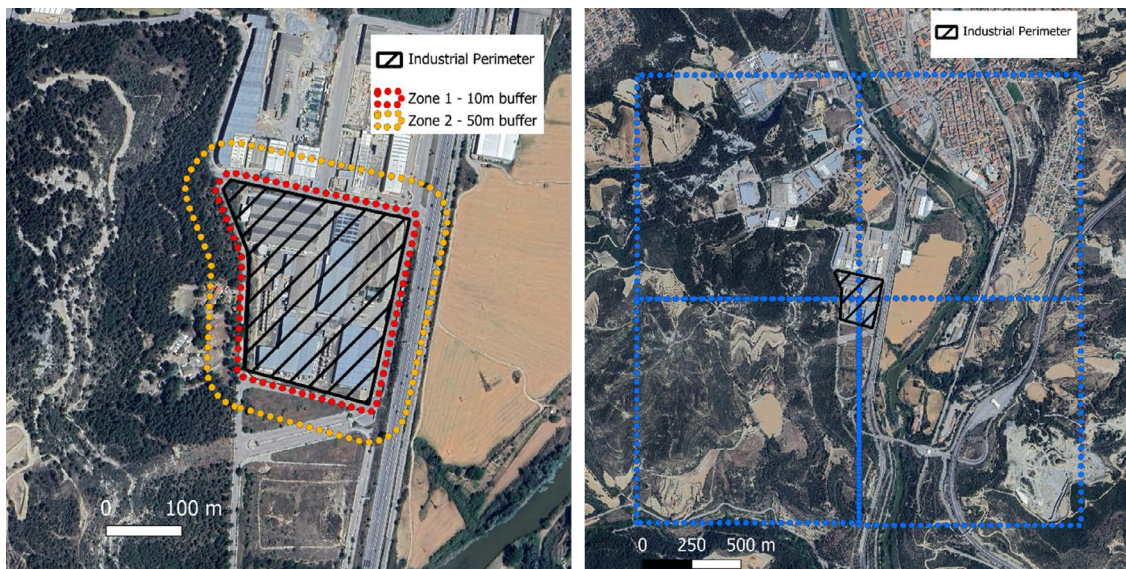


Figure 2: Examples of zone areas definition on satellite images for an industrial plant area. Left: zones 1 and 2. Right: zone 3.

The Wildfire Impact: **Zone 1** and **Impact**

- **Zone 1: < 10 meters**, including the entire infrastructure, all the equipment inside, and the immediate (<10 meters) environmental surroundings. The condition of infrastructure equipment and vegetation within this zone determines the vulnerability of the infrastructure to wildfire ignition, and therefore influences the severity of the possible wildfire impact.
- **Impact:** This subsection includes questions related to the estimated impact in terms of money and service disruption in case of wildfire damage. Please consider worst case scenarios when answering questions in this section.

2.3 Risk Assessment Procedure

To complete the assessment, please refer to the separate risk assessment worksheet (Excel document which will calculate the scoring automatically).

There are dedicated wildfire assesment sections for **Zone 3 and Zone 2**, which estimate the likelihood of a widfire hazard occuring and reaching the infrastructure, and for **Zone 1 and the Impact**, which estimate the factors influencing the severity of the impact of the wildfire reaching the infrastructure.

After answering each question, you will obtain two scores relating to the wildfire hazard, and the possible wildfire impact. These two scores are combined in a risk matrix to give one overall score for the infrastructure risk.

Sections of Risk Assessment	Estimating Risk Component
Zone 3 and Zone 2	Wildfire Hazard
Zone 1 and Impact	Wildfire Impact

STEP 1: ASSESSING WILDFIRE HAZARD – ZONE 2 AND ZONE 3

Information/tools needed:

- Internet access to consult specific webpages on national wildfire risk and hazard.
- Recent satellite images of area up to 1 km radius distance from industrial area perimeter.
- Measure 1 km, 50 m, and 10 m buffer distances from the infrastructure perimeter outlining the outer perimeter of Zone 3, 2, and 1 respectively. Divide Zone 3 and 2 in four quadrants.
- General information within this area on: terrain slope, vegetation type and condition, urban and industrial areas.

Zone 3: General wildfire risk

1. Check the average Average Annual Burned Area in hectares for your country by checking the Copernicus EFFIS wildfire statistics – the value is indicated by the blue bar in the graphs, and under the column called “Annual Avg. (ha)”. Click this URL to view the page: <https://forest-fire.emergency.copernicus.eu/apps/effis.statistics/estimates>
2. Check the current wildfire danger level – related to the recent climate conditions - of your region on <https://forest-fire.emergency.copernicus.eu/apps/fire.risk.viewer/> On the left EFFIS Wildfire Risk Viewer options select “Danger” and turn on the “Danger by weather (FWI30-day)”. Check the Danger by weather in your area by either clicking the point on the map closest to your infrastructure, or by enabling the 'legends' option on the left hand side of the website (shown by three dots and lines icon) and matching the corresponding legend colour and value.

Zone 3: Surrounding environment flammability




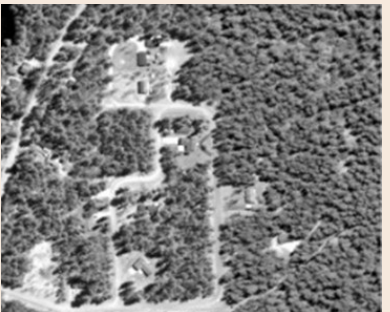
- On recent satellite images or vegetation maps, divide the environment surrounding of your infrastructure in 4 quadrants of at least 1km length – see figure 1 and figure 2 from this guide for a visual representation and an example of this procedure.
- Obtain the necessary information regarding vegetation type and condition in forested or wildland areas surrounding your infrastructure. Answer the questions provided for each quadrant surrounding your infrastructure, giving scores to the conditions that apply to most of the quadrant area.

***NOTE:** Attempt to choose the best answers that describe the majority of vegetation in each quadrant. Use Google Street View to get a view of the vegetation if you are not familiar. The objective is to increase your awareness of the surroundings of your plant and where the most likely wildfire threats can arrive from.

Table 1 provides photos illustrating the types of vegetation and of wildland-urban interface areas that are options in the scoring guide:

- Forest photos are from (European Environment Agency, 2007), more detailed information on European Forest Flammability can be found in (Xanthopoulos *et al.*, 2012).
- Photos of different wildland and urban interface areas are from (Bar-Massada *et al.*, 2014).

Table 1:
Photos of examples of the types of forest and wildland-urban interface types mentioned in the assessment questions

	Medium Risk (Score 1)	High Risk (Score 2)
Forested Area	<p>Deciduous Forest Example</p>  <p>Oak Forest</p>	<p>Coniferous Forest Example</p>  <p>Mediterranean Black Pine Forest</p>
Wildland-Urban Interface and Wildland-Urban Intermix	 <p>Wildland-Urban Interface</p>	 <p>Wildland-Urban Intermix</p>

The type of vegetation and the density and continuity of vegetation (if it is present continuously without break in between vegetation) influences how likely and how intensely a wildfire can burn. Furthermore, having industry and urban housing can increase the risk as it increases the changes of wildfire ignition and can potentially cause more intense wildfire exposure if wildfires ignite the urban areas and compromise fire fighting.

Zone 2: Infrastructure Location and Slope

1. This section of the assessment evaluates proximity and positioning relative to fire-prone areas as well as the terrain slope, and the relative location of your infrastructure, which influences fire spread (see *Section 1.1*).
2. For guidance on assessing the slope location and steepness please refer to *Figure 3*:

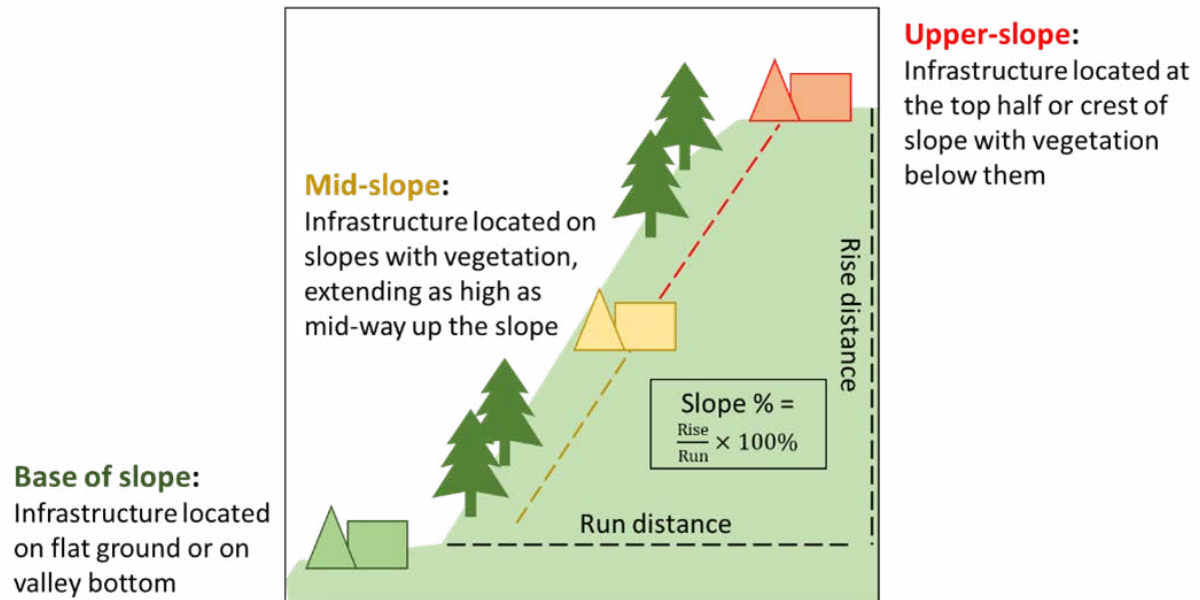


Figure 3: Schematic of slope location and characteristic information requested in the assessment.

STEP 2: ASSESSING WILDFIRE IMPACT – ZONE 1 AND IMPACT

Information/Tools Needed:

- Map of the industrial installation site and 10 m surroundings from the industrial installation perimeter.
- Divide your industrial site in components/areas of interest from external fire damage. Each building and warehouse would be a separate area, and a group or storage tanks bin would also count as one individual area.
 - Count how many buildings or warehouses, and how many storage areas are present. You will be asked to insert this number and answer questions over each.

Zone 1: Onsite Fire Spread Propagation Potential

1. To assess the vulnerability of wildfire spreading within Zone 1 perimeter, answer the questions regarding the presence of vegetation and other thermally-susceptible elements (wood, plastic, fuel drums) located within zone 1 (your industrial installation area and the 10 m surrounding it) paying special attention to materials within the infrastructure perimeter and near structures and equipment.

Zone 1: Onsite protection systems & Electrical Equipment

Questions in this section assess the condition and material of the electrical equipment that might be affected by wildfire, as well as onsite existing protection systems.

Zone 1: Building Structures

1. In these sections you will enter the number of identified buildings and relevant industrial installation areas. Please enter the number of storage tank areas and buildings, in the cells next to the question.

***NOTE:** storage tank areas refer to the entire open area of storage tanks – not individual tanks or enclosed storage of tanks.

2. Scoring cells will appear automatically for the number of areas indicated. You can type in a code for each area for your convenience in the “Area Code” row. To revert to only one column please delete the number inserted in the cell asking for number of areas.

***NOTE:** ensure you are using a .xism file format of the assessment for this feature.

***NOTE:** “Essential equipment” refers to necessary equipment for correct functioning of the plant economic or safety processes.

Impact: Impact and evacuation routes and plans

1. Estimate the impact of your infrastructure in case of wildfire by assessing potential financial losses and related economic disruptions.
2. Evacuation routes and evacuation plans are also assessed to consider the evacuation safety in case of wildfire impact – wildfire should be considered as included in emergency plans if there is specific considerations on how wildfires affect decision making and emergency response.

STEP 3: HOW THE ASSESSMENT IS SCORED AND INTERPRETED

- **The scoring cells automatically add and normalise the scores for each subsection and section:** the average of all scores provided for each section (Zone 1, Zone 2, Zone 3 and Impact) provides four final section scores, these are in turn summed and averages to give a wildfire hazard score (Zone 3 & Zone 2) and a wildfire impact score (Zone 1 & Impact), ranging from 0 – 4.
- **Important:** a score of 0 does not correspond to zero risk, it is an indicative value to represent relatively low risk, compared to higher scores. The numerical ratings are indicative, relative numerical indicators, and do not correspond to calculated probabilities.
- **The final Wildfire Hazard and Wildfire Impact rating appear in the scoring sheet. When all the scoring cells are filled in, the risk matrix will show the overall score.** Risk Matrix (Figure 4) and Overall Risk Score Interpretation (Table 3) are given below.

		Wildfire Impact (Zone 1 & Impact)			
		$0 \leq I < 1$	$1 \leq I < 2$	$2 \leq I < 3$	$3 \leq I \leq 4$
Wildfire Hazard (Zone 3 & Zone 2)	$0 \leq H < 1$				
	$1 \leq H < 2$				
	$2 \leq H < 3$				
	$3 \leq H \leq 4$				

Figure 4: Wildfire risk matrix to interpret the ratings for wildfire hazard and wildfire impact cumulatively

Table 3: General recommendations related to the final risk matrix score

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

3. Risk-Reduction Recommendations

Below find more detail steps and actions that can be taken to address the wildfire risk, in specific areas addressed and scored in the risk assessment. Remember that for high-risk scores relating to Zone 1 and your infrastructure impact, additional detailed risk assessments, and specifically designed risk-reduction measures should be considered and implemented.

Wildfire Hazard: Zone 3 and Zone 2	Recommendations
<i>Regional wildfire history and climate</i>	<p>Check regular updates on wildfire risk in national, regional, and local area – at relevant sources, some examples are given below:</p> <ol style="list-style-type: none"> 1. European Forest Fire Information System (EFFIS) – https://forest-fire.emergency.copernicus.eu/apps/effis_current_situation/ 2. Spain: https://www.aemet.es/es/eltiempo/prediccion/incendios 3. Portugal: https://fogos.pt/ 4. Greece: https://civilprotection.gov.gr/xartis
<i>Surrounding environment flammability</i>	<p>Contact surrounding industries or local community councils to get informed about their wildfire awareness and prevention strategies, recommend and advise them in conducting wildfire risk assessment and risk reduction measures.</p>
<i>Evacuation routes and plans</i>	<p>Update or create evacuation plans which consider possible wildfire obstruction in routes (if evacuation routes are surrounded by potentially burning vegetation).</p>
<i>Infrastructure location</i>	<p>Get informed about or get involved in clearing and maintaining surface vegetation and trees in forested areas surrounding your infrastructure perimeter.</p>

Severity of Wildfire Impact: Zone 1 and Impact	Recommendations
<i>Onsite fire spread propagation potential</i>	<p>Remove vegetation and thermally susceptible material on-site, or place them in protected areas, away from vulnerable buildings or infrastructure components.</p> <p>Create plan to maintain on-site vegetation to reduce or eliminate ignition risk. Follow the following general advice and guidance:</p> <ul style="list-style-type: none"> ▪ Remove vegetation whenever possible. ▪ Select low-flammability vegetation, general characteristics of low-flammability vegetation: Low oil or resin content, high moisture content, Green stems, Drought tolerant) ▪ Water the vegetation regularly, keep grass green, to prevent or delay ignition risk.
<i>Onsite protection systems</i>	<p>Ensure the fire protection systems are effective for the expected wildfire exposure mechanisms.</p>
<i>Electrical Grid Components</i>	<p>Replace and harden any vulnerable (to wildfire) infrastructure elements by replacing with more resistant materials, or installing fire detection and protection.</p> <p>Remove vegetation and thermally susceptible elements around the identified vulnerable infrastructure components and buildings.</p>
<i>Building Structures</i>	<p>Install metal mesh screens to any openings or vents in buildings.</p> <p>Replace or protect any combustible or vulnerable materials with more fire-resistant material.</p> <p>Replace glazing with double paned glazing or tempered glass.</p>
<i>Impact Assessment</i>	<p>Create a plan to address any supply chain disruption in case of impact to your infrastructure.</p>

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