

## **F. Fire Suppression**

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# Findings of Fact Regarding Fire Prevention and Mitigation

Organized by Tom Thompson Dec 2025

In light of the original Whitman County Wind Ordinance not having any requirements concerning fire prevention and suppression, here are findings of fact that show without question the need for a fire code to be in the ordinance. It is imperative that the county require specific measures to protect the lives and property of its residents and the environment. The pro-wind consultants Drs. McCunney and Ollson both recommended fire mitigation requirements for a wind ordinance.

All the following sources noted in this document are from the wind industry or those who service the wind industry. And so, the question remains as stated, "what measures are being taken to avoid preventable losses..."? **Feb 2023 Wind Power Magazine**

**We cannot trust the wind industry to regulate itself; it is up to Whitman County to take care of Whitman County! (Tom Thompson)**

Proposed Requirements by the Planning Commission on 11/19/25 as follows to **19.61.060 -Development Standards and Criteria**

## P. Fire Mitigation Requirements

1. Each nacelle/turbine to have a comprehensive fire detection system within the nacelle to detect and monitor for "rate of rise", heat, sparks, arc flash, and combustible gases. These systems will be capable of automatic shutdown of the turbine upon alarm. The detection system will be linked to a central alarm that will remotely notify operators and first responders.

2. Each nacelle/turbine will have an automated fire suppression system.

3. The developer/owner is required to annually submit emergency response plans with the initial application that have been coordinated with all fire departments/districts within 20 miles of the project boundaries. The plan will include water sources, fuel break locations and turbine shut down procedures. These plans shall be filed with the Whitman County Planning Department and all appropriate fire departments/districts. Plans shall resubmitted annually during the life of the project.

4. The project owners shall bear full financial responsibility for suppression costs and third-party damages from fires determined to originate from facility equipment or operations.

## Summary of Findings

**Finding #1: Wind turbine fires are under reported and there are no universal requirements to enforce reporting:**

- a) Oct 2020 Wind Power Monthly: "Fires at wind farms underreported over fears of reputational damage"
- b) 7-Sept-2023 Exponent Company: "Fire Suppression Systems in Wind Turbines"
- c) Feb 2023 Wind Systems Magazine: "Wind Turbine Fire Risk, the Time to Act is Now"

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- d) No date given, Firetrace International: "An Overview of Wind Turbine Fires"

## **Finding #2: There are no national or international mandates that require fire protection standards for wind turbines**

- a) 22-Feb-2021 Firetrace International Publication: "Will Fire Protection be Required on all Wind Turbines?"
- b) 3-April-2020 Firetrace International Publication: "Understanding Wind Turbine Fire Options"
- c) 22-Feb-2021 Firetrace International Publication: "Will Fire Protection be Required on all Wind Turbines?"
- d) 3-April-2020 Firetrace International: "Understanding Wind Turbine Fire Protection Options"
- e) No date given, Salgrom.com: "How to Enhance Wind Turbine Fire Safety"
- f) No date given, Firetrace International: "How to Evaluate Fire Risk at Wind Farms",

## **Finding #3: Large Turbines such as the Vestas V163-4.5MW pose a greater fire danger**

- a) Salgrom Company website: "Larger turbines (>3MW) show fire vulnerability due to increased electrical loads..."

## **Documentation and Sources for Findings**

### **Why do we need these requirements?**

The county residents need protection of their properties and lives, therefore is reasonable for the county to require fire mitigation requirements for all energy developers. The Palouse has red flag warnings at different times in the Spring, Summer and Fall seasons. It's the county's responsibility to set the standards for those who want to come into Whitman County to do business and make a profit. It only takes one fire to wreak havoc on the community!

### **1) Finding #1: Wind turbine fires are under reported and there are no universal requirements to enforce reporting**

It is a fact that wind companies under report fires, as per the following examples:

- a) **Oct 2020 edition of Wind Power Monthly**, entitled *Fires at wind farms 'underreported over fears of reputational damage'*. "Industry-wide underreporting of fires at wind farms has led to poor risk mitigation and damage prevention strategies, a report from a fire suppression firm has found. Firetrace International's report, called *In the Line of Fire*, looks at the threat of wind farm fires amid changes in turbine technology and the climate. It draws insights from wind industry fire experts about how manufacturers, operators and investors can respond to an evolving threat of fire. The fire specialist says that because of a lack of reporting and transparency around wind farm blazes, it is difficult to know how far off current estimates (ranging from 1 in 2,000 turbines to 1 in 15,000 ) are from the true number of fires each year, while many figures are more than five years out of date."

Link to article: <https://www.windpowermonthly.com/article/1697822/fires-wind-farms-underreported-fears-reputational-damage#:~:text=The%20fire%20specialist%20says%20that,offshore%20giants%20and%20skills%20shortages.>

- b) **7-Sept-2023, Exponent.com**, which engineers solutions and diagnosis to industrial issues, has an article entitled *Fire Suppression Systems in Wind Turbines*. It states “The industry is also facing criticism over the validity of its fire statistics. Research from the past decade, for example, suggests wind turbine fires may have been underreported, while newer studies question whether outdated figures are applicable to today's more complex turbines.”

Link to article: <https://www.exponent.com/article/fire-suppression-systems-wind-turbines#:~:text=Each%20wind%20farm%20requires%20careful,turbine%20and%20its%20transformer%20unit.>

- c) **Feb-2023 Wind System**: “Wind-Turbine Fire Risk”, Less transparent, though, is industry-wide data on details such as how many turbines burn down and the full cost of damages when they do. Most often, these facts are known only to insurers and project owner-operators.

*The recent fire to a Vestas V90 2MW turbine at Galgenberg wind farm in southwestern Germany -- for which, in the absence of lightning, investigators have so far struggled to identify the cause -- brings the wind sector's lax attitude to controllable risks under the microscope once again.*

*As this and other recent incidents have shown, once a turbine catches fire, there is little authorities can do but try to secure the area from flaming debris and monitor the flames as they burn themselves out.*

*Again, this is not an isolated occurrence. Mere days later, a Senvion turbine caught fire at Cullerin Range wind farm in New South Wales with investigations yet to understand the cause. And in late October 2022, a Vestas V110-2.0 turbine caught fire at Diamond Trail wind farm in Iowa County. In this instance, the flames spread to the field below, and several other turbines had to be taken offline for additional inspections to assess the fire risks, which lead to further disruption and lost revenue.*

*The question that will increasingly be asked of the wind industry, as it continues to grow, is what measures are being taken to avoid preventable losses like these? “*

Link to article: <https://www.windsystemsmag.com/wind-turbine-fire-risk-the-time-to-act-is-now/>

- d) **Firetrace International**: An Overview of Wind Turbine Fires, states “Research conducted by Caithness Windfarm Information Forum (CWIF) found that over the last five years, the average number of wind turbine fires was 25.4. Other researchers feel the number of cases of turbine fires is significantly underestimated based on the fact that there is no required reporting for turbine fires. Also, in the case of official reports, the reports can be incomplete, biased, or contain non-publicly available data. In a previous report, the Telegraph and Renewables UK both have estimated that 91 percent of wind turbine fires go unreported. With the average cost of a wind turbine fire at \$4.5M, the annual financial impact could be anywhere from \$114.3M to \$1.35B.”

Link to article: <https://www.firetrace.com/wind-turbine-fire#:~:text=In%202019%2C%20according%20to%20the,are%20ahead%20of%20structural%20failure.>

- e) **Firetrace International**: “How to Evaluate Fire Risk at Wind Farms”, page 6, “There seems to be little evidence that wind farm operators are conducting ‘holistic fire risk assessments’ following some type

of recognized standard” JP Conkwright, Assistant Professor of Fire Protection & Safety Engineering Technology at Eastern Kentucky University.

Link to article: [https://www.firetrace.com/hubfs/\\_img/reports/Firetrace-Report-How-To-Evaluate-Fire-Risk.pdf?utm\\_campaign=Wind%252520FY22&utm\\_source=Tamarindo&utm\\_medium=direct-download&utm\\_content=fra-report](https://www.firetrace.com/hubfs/_img/reports/Firetrace-Report-How-To-Evaluate-Fire-Risk.pdf?utm_campaign=Wind%252520FY22&utm_source=Tamarindo&utm_medium=direct-download&utm_content=fra-report)

## 2) Finding #2: There are no national or international mandates that require fire protection for wind turbines

In other words, it’s highly unregulated, kind of a wild west compared to many other established industries.

- a) **22-Feb-2021 Firetrace International**, an article entitled “Will Fire Protection be Required on all Wind Turbines?”, that fire regulations are much vaguer for wind turbines. *“Fire regulations are common in many industries. Buildings and factories are a couple of examples. They establish a baseline of best practices to keep people safe from fire risks. However, fire regulations are much vaguer for wind turbines. Certain standards exist as guidelines (NFPA, CFPA, VDS), but ultimately it is up to the Authority Having Jurisdiction (AHJ) to decide what fire safety steps are required in most cases. Some AHJs have been proactive regarding wind turbine fire protection and have made detectors and/or fire suppression systems required. Others are leaving the bulk of fire protection up to the turbine manufacturers, developers, and owners.”*

Link to article: <https://www.firetrace.com/fire-protection-blog/wind-turbine-fire-regulations#:~:text=Fire%20regulations%20are%20common%20in,or%20fire%20suppression%20systems%20required.>

- b) **3-April-2020 Firetrace International** article entitled “Understanding Wind Turbine Fire Protection Options”, states *“Just as there is no official required reporting of wind turbine fires, there is not an international or national mandate for fire protection requirements. The most recognized guideline, but not a requirement, is NFPA 850, which recommends fire protection for electric generating plants and high voltage direct current converter stations. Also, in the U.S., the Occupational Safety and Health Administration (OSHA) strongly recommends the installation of fire protection equipment. Wind farm operators having rigorous safety standards and programs in place, do adhere to these guidelines, and implement fire protection measures.”*

Link to article: <https://www.firetrace.com/wind-turbine-fire#:~:text=In%202019%2C%20according%20to%20the,are%20ahead%20of%20structural%20failure.>

Therefore, it’s up to the county to ensure that the residents and their properties are protected as much as possible. The county needs to do this, NOT the wind developer, NOT the state of Washington, but the county!

- c) **22-Feb-2021 Firetrace International**, an article entitled “Will Fire Protection be Required on all Wind Turbines?” Firetrace International states one of the reasons that wind turbine regulations may increase in the future is...*“Because of the large payouts, premiums in renewables have increased by*

20-30%. Even if your own company did not experience a fire, the insurers still had to pay out claims, and increase premiums across the board as a result.”

Link: <https://www.firetrace.com/fire-protection-blog/wind-turbine-fire-regulations>

So, there have been problems with renewables, causing them to have large payouts because of fires and other damages they have cause. (Google Moss Landing Disaster for kicks). The county needs to have strict guidelines to protect the citizens and environment. Hence, the need for fire liability provided by the project owner in the event of a fire.

- d) **3-April-2020 Firetrace International:** The need for fire prevention and suppression in wind turbines is extremely important, due to the fact once a fire starts in the nacelle, it’s virtually impossible to put it out as stated in a Firetrace International article from April 3, 2020 entitled “Understanding Wind Turbine Fire Protection Options”: *It is nearly impossible to put out a wind turbine fire using manual fire-fighting methods. The height of turbines, potential of the blade still rotating, and the remote locations many wind farms make them difficult, if not impossible, for local fire departments to battle. Combustible materials in the wind turbine are also risk factors. Composite materials are found in the blades, nacelle walls, and an estimated 235 gallons of lubricating oil and other highly combustible liquids that are held in the nacelle. These oils and liquids are used in the gearbox, yaw, hydraulic system, blade pitch change mechanism, oil pumps, mechanical brake, and oil-filled transformer. All that is needed is an ignition source to spark a fire.*

Link to article: <https://www.firetrace.com/fire-protection-blog/wind-turbine-fire-protection>

- e) **No date given, Salgrom.com website:** “How to Enhance Wind Turbine Fire Safety”. Fire protection and suppression measures are essential to prevent environmental and cascading issues that come with fires, as stated by the Salgrom company in Finland, which makes fire extinguishing systems: *“Wind turbine fires create cascading safety concerns that extend well beyond the immediate structure. For maintenance personnel, nacelle fires present life-threatening situations due to limited escape routes from heights of 80-120 meters. Emergency evacuation often depends on specialized equipment that may be compromised during fire events. Environmental impacts include potential soil contamination from burning composite materials, lubricants, and hydraulic fluids. A single turbine fire can release harmful particulates across substantial areas, particularly concerning in ecologically sensitive regions. Furthermore, burning debris can ignite vegetation fires in dry conditions, potentially affecting several square kilometers.”*

Link to article: <https://salgrom.fi/en/how-to-enhance-wind-turbine-fire-safety/#:~:text=Improving%20fire%20protection%20for%20wind,incidents%20and%20their%20potential%20consequences.>

### 3) Finding #3: Large Turbines such as the Vestas V163-4.5MW pose a greater fire danger

- a) **No date given, Salgrom.com website.** As stated by an article on the Salgrom Company from Finland which manufactures fire extinguishing systems, entitled “How to Enhance Wind Turbine Safety”, as stated: *“Larger turbines (>3MW) show fire vulnerability due to increased electrical loads...Communities near wind farms face risks from falling debris, with burning fragments documented traveling up to 500 meters from the turbine bases.”*

Link to article: <https://salgrom.fi/en/how-to-enhance-wind-turbine-fire-safety/#:~:text=Improving%20fire%20protection%20for%20wind,incidents%20and%20their%20potential%20consequences>.

# Fires at wind farms 'underreported over fears of reputational damage'

Poor data and lack of rigorous and transparent reporting around blazes raise concerns operators are left guessing over protection, according to an expert report

by Andrew McCorkell 20 October 2020 / **WindPower Monthly**



**An image of a burned-out turbine from the Firetrace report**

Industry-wide underreporting of fires at wind farms has led to poor risk mitigation and damage prevention strategies, a report from a fire suppression firm has found.

Firetrace International's report, called *In the Line of Fire*, looks at the threat of wind farm fires amid changes in turbine technology and the climate. It draws insights from wind industry fire experts about how manufacturers, operators and investors can respond to an evolving threat of fire.

The fire specialist says that because of a lack of reporting and transparency around wind farm blazes, it is difficult to know how far off current estimates (ranging from 1 in 2,000 turbines to 1 in 15,000 ) are from the true number of fires each year, while many figures are more than five years out of date.

It identifies risks from global warming, ageing turbines, new materials, offshore giants and skills shortages.

F-2

Chris Streatfeild, director at health and safety consultant Forge Risk, said that companies are “fundamentally going in the right direction in terms of health and safety”, and that the industry has a good track record on managing fire risk.

However, he added: “I think we need to take data ownership. The industry certainly has opportunities to be better about sharing and communicating data about incidents, because we need to share, and we need to learn from it.

“I fully understand the industry’s caution, but I think we should be more open, more upfront and more willing to own the issue.”

### **Challenges**

- **Negative reputation:** A lack of transparency over fires in the industry means opponents can set the agenda on wind’s safety record, Firetrace argued.
- **Operator uncertainty:** A lack of robust figures means wind farm owners and operators find it difficult to decide what level of fire protection they need.
- **Old data:** A reliance on turbine fire data from the mid-2010s means companies can’t spot recent fire trends to tackle them

Firetrace argues that their insurers and manufacturers' reports of how often wind turbines catch fire "vary wildly".

In 2020, Wind Power Engineering magazine estimated that one in 2,000 turbines would catch fire, while one in 10,000 was the figure offered by Fire Protection Engineering magazine in 2019.

And Firetrace cites an independent fire expert who says that the risk of a catastrophic fire, where a turbine is destroyed, is one in 15,000.

Firetrace added that if one in 2,000 turbines catches fire each year, it suggests that a typical wind farm with 150 turbines would be hit by one or two fires in 20 years of operation.

It also stated that the risk of wind turbine fires will change alongside the climate and technological trends.

### **Global warming**

In 2020 there have been devastating wildfires in Australia and the US, exacerbated by climate change, rising temperatures and droughts, creating the perfect conditions for fire.

These conditions expose turbine operators to additional risk, Firetrace stated.

The research cites examples where turbines have been struck by fire.

A turbine fire at the [120.6MW Buffalo Gap](#) wind farm in Texas in August 2019 sparked the 1km<sup>2</sup> Rhodes Ranch 3 Fire in Mulberry Canyon.

In July 2020, another turbine fire in Texas that caused a 13km<sup>2</sup> wildfire in Nolan County. And in July 2019, a turbine fire at the [151.2MW Juniper Canyon Phase 1](#) wind farm in Washington state ignited the surrounding grass and brush after melted sections fell to the ground. The blaze sparked a 1km<sup>2</sup> wildfire.

The research points to such fires exposing operators to legal claims from neighbouring landowners even if there was no negligence by the operator, potentially provoking legal battles between insurers, manufacturers and operators.

### **Ageing turbines**

As the first major wave of turbines installed in the mid-1990s come to the end of their operational lives, around 7% of the total current wind fleet is now more than 15 years old, the research states, alongside 28% in Europe due to the maturity of the sector.

Firetrace raises concerns over older models that may be less reliable – because of less sophisticated technology – that can exacerbate problems in the three primary ignition sources in typical turbines.

These are the converter and capacitor cabinets in the nacelle, the transformer and the nacelle brake area.

Firetrace adds: “The hydraulic area is sometimes considered a fourth ignition source. Of these three primary ignition sources, most fires start in the converter cabinet or capacitor cabinet in the nacelle. Most fires are caused by electrical failures, from short circuits or cable failures to overloading or generator problems.”

### **New materials**

The research suggests risks with older machines may be well-known, but that this may not be the case with materials in new turbines, such as fibreglass used in blades.

Firetrace cites JP Conkwright, turbine fire investigator and assistant professor of fire protection and safety engineering technology at Eastern Kentucky University, who said that making turbine blades out of fibreglass may expose workers to “explosive dust” during repairs.

He said: “We’re doing a lot of blade repairs. We’re doing a lot of internal blade repairs, and the fibreglass dust is much more explosive than normal dust. We’re inside a confined space, 300 feet in the air, creating fibreglass dust with a grinder.”

Meanwhile in Europe wooden turbine towers are a good environmental solution, but concerns were raised over safety, especially in confined spaces, hundreds of metres in the air, where there may be fibreglass dust.

### **Offshore**

Size matters offshore, the report stated, with manufacturers now offering 13MW and 14MW turbines.

As big as skyscrapers and many miles from dry land, they pose a different set of risks from those in onshore wind, though Firetrace added that so far industry is managing them well.

Friretrace cites G+, the global health and safety organisation for offshore wind, saying there has been no fire incidents at offshore wind farms in 2018, 2019 or in the [most recent set of statistics](#) from the first quarter of 2020.

The company did warn that operators and investors should remain very aware that the costs of a catastrophic fire at an offshore wind turbine would be huge.

### **Skills shortages**

The potential impacts of skills shortages among skilled operations and maintenance (O&M) technicians mean potential fire risks, the research states.

In the US, wind farms totalling 9.1GW were [commissioned in 2019](#), which was the third-highest year on record – with 4.4GW in the first six months of 2020.

Now there are more than 60,000 turbines totalling 109.9GW in the US, with just 7,000 technicians to manage that fleet.

The stark contrast in figures has led O&M specialists to warn of a [shortage of skilled technicians](#). Operators need contractors to deliver projects cheaper by driving down costs, raising concerns over service quality.

Owners need to remain vigilant so that this doesn't "store up extra fire risks" in the coming years, the report concluded.

Web Address: <https://www.windpowermonthly.com/article/1697822/fires-wind-farms-underreported-fears-reputational-damage>



From Exponent.com

THOUGHT LEADERSHIP

# Fire Suppression Systems in Wind Turbines



September 7, 2023

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## Adopting proactive fire prevention strategies can help wind farm operators prepare for continued industry growth and growing regulatory scrutiny

Last year, wind farms in the U.S. passed an energizing threshold, supplying over 10% of the country's grid-tied electricity. Yet [for the 72,000 wind turbines now spinning](#), fire suppression systems remain optional.

Why?

One reason lies in [the light historical regulatory touch](#) applied to wind turbines, a carryover from the wind industry's 1990s origins in small-scale electrical generation. Additionally, turbine fires are considered rare and infrequently associated with life-threatening damage.



For operators, the combination of light regulatory pressure and a low incident rate has minimized incentives to actively install fire suppression systems. The National Fire Protection Association provides recommendations for fire safety of wind turbines in NFPA 850 "Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations."

## Rethinking fire suppression and regulations for wind turbines

Although changes have yet to be announced for wind farms, there are indications that this hands-off regulatory approach to wind turbine fire safety could be poised for change.

At the local level, communities like Shasta, California, have been shooting down wind energy proposals due to [concerns over the increased threat of wildfire](#) and the difficulty of aerial fire-fighting over forestland. The industry is also facing criticism over the validity of its fire statistics. [Research from the past decade](#), for example, suggests wind turbine fires may have been underreported, while [newer studies](#) <sup>1</sup> question whether outdated figures are applicable to today's more complex turbines.

Perhaps most importantly, the wind industry is [growing significantly](#). By decade's end, over 100,000 wind turbines — many of which will be part of an advanced generation of more powerful turbines — will be operating at U.S. grid-scale wind farms. The majority of those farms will be located near [wilderness or on open plains](#), with growing implications for the potential impacts of any turbine fires.

At such a scale, wind turbine manufacturers, owners, and operators can expect the maturing wind industry to see increased regulatory scrutiny. Coupled with the low cost of installing or retrofitting fire suppression systems compared to the high probability of total turbine loss in the event of a fire, advancing from reactive to proactive fire safety strategies can help stakeholders prepare for the future of wind farm regulations now.

*Many nacelle fires lead to total turbine losses or pose significant downtime for wind farms.*

## Fire prevention strategies for the primary origin of wind turbine fires

While most turbines come equipped with lightning protection systems, limited protection is provided against other potential fire causes for the most common ignition location in wind turbines: the nacelle. The nacelle is the electrical box at the center of

the turbine that houses a tightly shared space for the gearbox, generator, cables, and electronic systems. [Ninety percent of wind turbine fires begin in the nacelle](#), where combustible materials lie in proximity to electrical wiring and rotating machinery.

Nacelle turbine fires typically begin in one of [three areas](#): the converter and capacitor cabinets, the transformer, or the brake. Electrical faults or mechanical overheating can lead to ignition of polymeric components or lubricating oils. With the abundance of fuel and high wind speeds, fires can start and grow quickly to engulf the fiberglass nacelle and surrounding plastics. [Many nacelle fires lead to total turbine losses](#) or pose significant downtime for wind farms.



Each wind farm requires careful engineering and environmental assessments to determine the right combination of fire suppression systems and strategies, but at a high level, common opportunities to reduce fire risk include:

- Installing an automatic fire suppression system, such as a clean agent, inert gas, or aerosol extinguishing system.
- Replacing polymer composites with advanced fire-resistant materials and using non-combustible hydraulic and lubricating oils.
- Integrating traditional detection systems, such as heat and smoke detectors, linear

heat detecting cables, and air-purification systems, wired through a turbine's existing supervisory control and data acquisition system (or SCADA). This can permit remote notification of a developing fire and support rapid response.

- Substituting mineral-oil-based products with synthetic lubricating oils that can help reduce combustion of the hundreds of gallons of oil held in the turbine and its transformer unit.

**\$5M**

cost of new turbine

**\$10K**

starting cost to retrofit

## Growing incentives for fire suppression systems in wind turbines

Technological advancements in turbine capacity and recent industry disclosures about aging turbine components suggest that an unprecedented number of wind turbines will be installed, repaired, or replaced in the next few years.

With some new, upgraded turbines running approximately \$5 million each to install, the wind industry may have developed an internal incentive to adopt fire suppression systems, some of which can have retrofit price tags between \$10,000 and \$30,000. As wind farms prep for eventual replacements, retrofitting fire suppression systems remains a viable interim opportunity to both safeguard existing turbines and increase the ability of operators to coordinate fire protection across their facility's footprint, which typically extends over thousands of acres.

In addition, the ongoing trend of developers buying wind farm projects through power purchase agreements means that stakeholders can find themselves with a mixed fleet of turbines sourced from multiple manufacturers. In such cases, procuring fire suppression systems may require extra legwork to streamline retrofits and sync with hazard response systems.

## In advance of regulations, wind turbine fire suppression remains optional — but important

The growth of wind power means more people rely on it. Across the U.S., new onshore turbines are being installed at a rate of about 3,000 per year. In Texas, for example,

which boasts 75% of the nation's wind turbine fleet, [wind power generated 25% of the state's electricity](#) in 2022. Numbers like that make it clear that the stakes are rising for safeguarding wind farm assets and operations.

While federal regulations mandating fire suppression at wind farms remain in development, the growing cost and value of individual turbines means that wind farm stakeholders have ample motivation to pursue fire suppression retrofits and designs on their own accord.



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TURBINE MAINTENANCE

# WIND-TURBINE FIRE RISK: THE TIME TO ACT IS NOW

Figures on the likelihood of a wind-turbine fire range between 1 in 2,000 to 1 in 7,000 turbines. (Courtesy: Firetrace)

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## *Industry attitude toward managing avoidable problems such as fire damage lacks rigor, but the time to change this attitude is now, on the eve of historic development in the wind sector.*

By ROSS PAZNOKAS

**W**ind turbine fires are relatively rare. But when turbines do catch fire, the ensuing spectacle of rotating flames and falling debris is impossible to ignore.

Less transparent, though, is industry-wide data on details such as how many turbines burn down and the full cost of damages when they do. Most often, these facts are known only to insurers and project owner-operators.

The recent fire to a Vestas V90 2MW turbine at Galgenberg wind farm in southwestern Germany -- for which, in the absence of lightning, investigators have so far struggled to identify the cause -- brings the wind sector's lax attitude to controllable risks under the microscope once again.

As this and other recent incidents have shown, once a turbine catches fire, there is little authorities can do but try to secure the area from flaming debris and monitor the flames as they burn themselves out.

Again, this is not an isolated occurrence. Mere days later, a Senvion turbine caught fire at Cullerin Range wind farm in New South Wales with investigations yet to understand the cause. And in late October 2022, a Vestas V110-2.0 turbine caught fire at Diamond Trail wind farm in Iowa County. In this instance, the flames spread to the field below, and several other turbines had to be taken offline for additional inspections to assess the fire risks, which lead to further disruption and lost revenue.

The question that will increasingly be asked of the wind industry, as it continues to grow, is what measures are being taken to avoid preventable losses like these?

While it is true that learning the specific cause of a turbine fire can prove difficult, expensive, and time consuming, understanding how these assets can be protected from this risk, and acting upon this knowledge, is not.

### **WHO IS TAKING RESPONSIBILITY?**

The key obstacle to mitigating avoidable risks is the assumption that responsibility falls elsewhere in the supply chain.

The time and financial constraints pressing developers are such that to install fire suppression technology at the manufacturing stage is not a priority, even though it is available. Additionally, project owner-operators tend to assume fire risk has been "designed out." Experience shows this is not the case; it has merely been passed on to the owner-operators who need to retrofit the appropriate technology to protect their assets.

With owner-operators deferring responsibility of fire-risk management to developers, and vice versa, it is too often the case that risks are not managed at all. The result is an implicit attitude that the insurer will shoulder the costs if a fire indeed occurs. While more insurance capital is flowing into the market, the market is also hardening in

response to increased losses. Thus, owner-operators who are seen to be passing the tab onto insurers are at the mercy of underwriters increasing premiums accordingly.

Not only that, but the more the insured lean on insurance to pick up their risks, the greater the possibility that insurers will move to increase deductibles and remove coverage for lost revenue during periods of downtime in order to re-balance underestimated renewable energy risk portfolios. Since the average downtime after a wind-turbine fire is approximately 12-18 months, this could reach up to \$1 million per affected turbine.

Legislation also has a role to play in ensuring wind energy assets are adequately protected from fire. At present, there is very little standard legislation that mandates fire-safety precautions specifically for the wind sector.

In places such as Ontario, Canada, where some policies exist to enforce the use of vetted risk protection technologies, this is very much the exception rather than the rule. It is far more often the case that fire-safety features, though recommended, are left to the discretion of the owner-operator. Given that this comes at a cost, albeit less than the rounding error in renewable project budgets, the odds are increasingly stacked against the necessary management of fire risk.

All things considered, the lack of collective responsibility taken by key stakeholders in the wind sector to implement the requisite safety features is concerning, particularly ahead of an expected period of expansive growth.

### **HOW CAN OWNER-OPERATORS TAKE RESPONSIBILITY?**

Project owner-operators can play a pivotal role in changing the way in which the industry approaches fire risk management both in existing assets and in future assets.

In the case of the Vestas V90 turbine, the wind-farm operator, Windpark Saar, speculates that an issue with the braking system may have caused the fire. This, and other failures, are unexpected in a model that is only 7 years old. This incident serves as an example of how unpredictable problems can lead to catastrophic fire damage and demonstrates how this risk can only be effectively managed by the installation of a clean-agent fire-suppression technology.

Regardless of age, wind turbines are high-voltage machines that produce a lot of heat and are subjected to harsh weather conditions. Degradation and maintenance needs are to be expected. High-voltage cabinets, transformer rooms, brake and slip rings are all routinely checked for signs of wear, but not all of these parts are protected from fire risk even though they can be easily equipped with the technology.



As it stands, fire-suppression systems are nearly always retrofitted after a fire incident, rather than proactively ahead of an event. (Courtesy: Firetrace)

Currently, the industry focus is on building bigger wind turbines with more capacity – the most recent being a colossal 18 MW wind turbine released in China. However, even as the designs of new turbines increasingly upgrade the power production of the asset, there is no reason for owner-operators to believe their models will be equipped to mitigate risks such as fire. In fact, the only way they can be assured of this with new assets is by requesting that designers incorporate the relevant safety features and factor that into their expenditure.

Precise figures on the likelihood of wind-turbine fire range between 1 in 2,000 to 1 in 7,000 turbines depending on who you ask, but the salient point is this threat exists and affects turbines every year.

As it stands, fire-suppression systems are nearly always retrofitted after a fire incident, rather than proactively ahead of an event. Considering the cost of the lost asset, loss of revenue due to downtime, and the insurance increase per turbine after a fire event, this is equivalent to shutting the stable door after the horse has bolted. And this is before considering the impact of reputational damage and disruption to day-to-day business operations.

And so, the proactive installation of fire-suppression technology, either at the manufacturing stage or as fleet retrofit projects, represents a proactive and cost-effective

way for owner-operators to manage their risks and protect themselves against significant potential losses.

#### WHICH OTHER INDUSTRY STAKEHOLDERS CAN HELP DRIVE CHANGE?

The loss of an asset to fire has direct implications for insurers. It isn't just the potential \$9 million claim for cleaning up and replacing a damaged turbine, but the business interruption and lost revenue on top of that, which could amount to as much as \$2,000 a day.

According to data from GCube, a leading underwriter for renewable projects, insurers have seen a 38 percent increase in business interruption claims since 2016. As the price of premiums rise in response to this, there is a concern that this does more to consolidate, rather than deter, the attitude that the bill for fire damage can just be passed onto the insurer.

A possible middle-ground here would be for insurers to incentivize the retrofitting, or "opt-in" at the manufacturing stage, of fire-suppression systems with decreased premiums or lower deductibles for the project owner-operator to reduce the volume of annual claims related to fire.

With proven and bankable clean-agent fire detection and suppression solutions available in the market, it makes sense for insurers to encourage the insured to take up the

option to protect themselves against the worst-case scenario. This is already the case in more mature industries open to fire risk, such as manufacturing and machining, where insurers are offering discounts when sufficient risk-protection technology is proven to be in place.

## HOW GOVERNMENTS CAN TAKE RESPONSIBILITY

Government policy can play a powerful role in a unified industry approach to managing fire risk, too.

In a moment where wind projects are being deployed at a historic rate around the world to meet net-zero targets, governing bodies can ill-afford the reputational damage that comes with wind-turbine fires.

In spite of this, across much of North America, there is no mandate for even so much as a fire-risk assessment for wind-farm owner-operators, let alone fire-suppression systems. And though countries in Europe, such as Germany, have brought in such mandates in recent years, the stipulations of that legislation still leave room for owner-operators to interpret the risks and make their own decisions — as opposed to having legislation that directly dictates the behaviors and actions needed to protect the lives and livelihoods of the technicians and the community.

The wind sector in the U.S. has yet to introduce strict regulation, and it currently abides by the National Fire Protection Association 850 code that applies to all forms of power generation. This offers a set of recommendations but no requirements. As the sector primarily operates on a utility scale, it will only be a matter of time before strong, uniform guidelines surrounding fire risk are required.

What are the consequences of failing to change the industry's current attitude to fire risk?

According to the research of the International Association for Fire Safety Science (IAFSS), there is stubborn reticence to report wind-turbine fires. Going back to the years between 2006-2010, both The Telegraph and Renewable UK estimated a total of 1,500 wind-turbine fires. This, in contrast to the Caithness Windfarm Information Forum (CWIF) statistic of 142 reported cases in the same period, indicates that roughly 90 percent of cases go unreported.

Not only is this approach unsustainable as more wind projects are commissioned, but it also prevents the industry from understanding the true level of risk fire represents and, as a result of this lack of knowledge, from building the necessary best practice in response.

To ensure we make the most of this period of growth, the wind industry must now demonstrate its sustained



Government policy can play a powerful role in a unified industry approach to managing fire risk. (Courtesy: Firetrace)

commitment to safety. Failure to proactively protect against controllable risks like fire could set us back with the following issues:

- ✔ Unsafe work environments for on-site personnel.
- ✔ Unnecessary loss of assets to fire – the cost of which is often underestimated.
- ✔ Additional strain on already stretched supply chain.
- ✔ Increased insurance claims, leading to increased premiums, decreased coverages, and/or insurers leaving the renewables market.
- ✔ Increased risk of wildfires in surrounding areas.
- ✔ Reputational loss and public criticism of the industry.

What is essential now is that the sector works collectively to own these risks, rather than assuming someone else will take responsibility. Ultimately, project owner-operators need to take the lead and invest in clean-agent fire detection and suppression systems, but, equally, it is incumbent on the other stakeholders to encourage this best practice with incentives and policies.

If all parties work together, the risk of wind-turbine fires and their numerous safety, financial, environment, and reputational consequences will be drastically reduced — if not eliminated. ↵

## ABOUT THE AUTHOR

Ross Paznokas is the Global Business Development Manager-Clean Energy for Firetrace International, a global organization supporting renewable energy with suppression systems custom built for each client's unique application. More info: [www.firetrace.com](http://www.firetrace.com).

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## An Overview of Wind Turbine Fires

When a wind turbine catches on fire, it is no match for conventional fire fighting methods. Newer wind turbines stand, on average, nearly 500 feet from the base to the tip. The height and location of wind turbines create a unique set of fire safety challenges.

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F-5



As the global need for energy increases, and concerns on the impact that we are having on the environment, the demand for renewable energy grows. Wind power has a low environmental impact, and when comparing to conventional energy sources reduces carbon emissions, saves billions of gallons of water, and decreases the output of pollution. Over the previous five years, the increase in output from wind turbines has nearly doubled and can cover more than six percent of the global electricity demand. As more and more wind turbines come online and the fleet of current wind turbines age, there is a likely increase in wind turbine accidents, including wind turbine fires.

Due to the remote location of many wind farms and no current required reporting of turbine fires, a significant number of wind turbine fires go unknown. However, in this day and age, with quick access to the camera on your phone and the ability to post to social media from nearly anywhere, more wind turbine fires are being exposed. When comparing to other energy industries like oil and gas that have thousands of fire accidents a year, fire incidents in wind turbines remain relatively low. Still, the impacts are significant from the replacement costs, lost revenue, and environmental impacts.

## Insights on the Number of Wind Turbine Fires

In 2019, according to the [World Wind Energy Association \(WWEA\)](#), the growth rate of the wind market was 10.1 percent, the second strongest year in terms of market size. At the end of 2019, the global capacity of wind turbines was 650.8 Gigawatts. What does this mean in terms of fire risk for wind turbines? With the capacity of wind turbines increasing, the risk of fire also increases. Fires in wind turbines are the second leading cause of accidents after blade failure and are ahead of structural failure.

Wind turbines are also getting bigger in terms of capacity. While more efficient from an energy production standpoint, this means fires have increasingly large impacts. Wind turbine fires may have costed \$1M 10 years ago, but today they can average \$7-8 million for a total loss.

Research conducted by [Caithness Windfarm Information Forum \(CWIF\)](#) found that over the last five years, the average number of wind turbine fires was 25.4. Other researchers feel the number of cases of turbine fires is significantly underestimated based on the fact that there is no required reporting for turbine fires. Also, in the case of official reports, the reports can be incomplete, biased, or contain non-publicly available data. In a previous report, the Telegraph and Renewables UK both have estimated that **91 percent of wind turbine fires go unreported**. With the average cost of a wind turbine fire at \$4.5M, the annual financial impact could be anywhere from \$114.3M to \$1.35B.

## Helpful Links

- [Three Wind Turbine Fires Occurring in December Make Headlines](#)
- [Are some turbines more likely to catch fire than others?](#)
- [Is Fire Risk Increasing in the Wind Industry?](#)
- [Top 3 Types of Wind Turbine Failure](#)
- [5 High Profile Wind Turbine Fires](#)
- [The Wind Turbine Fire Problem, By the Numbers](#)
- [Report: In the Line of Fire](#)
- [What Does Fire Risk in Wind Energy Look Like Heading Into 2021?](#)

## Why Wind Turbines Catch Fire

Wind turbine fires are most likely to occur in the nacelle. Components within the nacelle are combustible and vulnerable to fire. Highly flammable materials like the hydraulic and transformer oil and plastics are located near electrical wiring and equipment. If an ignition source is introduced, a fire can start quickly and spread. Another area of concern in a turbine is the base of the tower. This area contains electrical monitoring equipment, which under the right circumstances, can catch fire after a failure.

For a fire to start, you need an ignition source. The number one cause of wind turbine fires is lightning strikes. Other causes are electrical or mechanical malfunctions and human error. These include:

- Loose, broken, or defective electrical components
- Short circuits
- Arcing in the transformer
- Electrical equipment being overloaded or overheating
- Failure of SCADA systems
- Inadequate lubrication between bearing surfaces, causing overheating and sparks
- Generator malfunction
- Mechanical braking system fault
- Maintenance work like welding or cutting
- Fire debris from forest or bush fires
- Manufacturing or construction defects
- Improper operations or maintenance
- Turbines not suited for local conditions

When dealing with fire risk factors, both the age of the turbine and geographic location can play a role. As fleets of wind turbines are getting closer to reaching the end of their lifespan, they pose a higher risk due to the aging components, wiring, etc. The geographic location can also have an impact. In areas with warmer and drier climates, cables, transformers, nacelle components, and the control cabinet are more susceptible to deterioration due to the temperature. All wind turbines should be on a strict routine maintenance schedule to ensure all components are in good working

condition.

### Helpful Links

- [Why Wind Turbines Catch Fire](#)

## Exploring Wind Turbine Fires

Based on research conducted by CWIF, since 2000 there have been 385 documented wind turbine fires. A number of these fires where not only a total loss of the turbine but had **devastating consequences**. In June 2012, the View Fire, which burned 367 acres in Riverside County, California, was caused by a wind turbine fire. Nearby residences were evacuated, and over 100 firefighters fought the wildfire to get it contained. A little over a year later, a tragedy that the wind industry had not yet experienced occurred. In October 2013, two young mechanics became trapped on top of a burning wind turbine and died as a result at the Piet de Wit Wind Farm. Because of the height of turbines, a specialized team of firefighters was called to battle the fire and recover the victims.

More recently, in the US, two wildfires were sparked from wind turbine fires. In July 2019, melted debris falling from a turbine fire caught the surrounding grass and brush on fire to cause the Juniper Fire wildfire, which put 39 structures in danger. It took almost 200 fire crew members to contain the 250-acre fire over three days. A turbine fire on August 26, 2019, is blamed for the Rhodes Ranch 3 Fire outside of Abilene, Texas. Record-setting temperatures and rough terrain increased the challenges for firefighters. Fire crews on the ground watched over the containment lines while aircrews spread fire retardant and water on hot spots. Luckily, in both cases, there were no reports of injury or structural damage.

Wind turbine fires are not something you want to face in your business because it can harm your assets, your staff, and the surrounding environment.

### Helpful Links

- [What Happens After a Wind Turbine Catches Fire?](#)

## Wind Turbine Fire Protection Options

When it comes to battling wind turbine fires, it is nearly impossible to do so using traditional fire fighting techniques. The location of wind farms, accessibility to individual turbines, and availability of water can be a challenge. Not to mention the height of turbines and the potential of the blade still rotating while on fire. The likely outcome for wind turbine fires is letting the turbine burn until it extinguishes itself.

Just as there is no official required reporting of wind turbine fires, there is not

an international or national mandate for fire protection requirements. The most recognized guideline, but not a requirement, is NFPA 850, which recommends fire protection for electric generating plants and high voltage direct current converter stations. Also, in the U.S., the Occupational Safety and Health Administration (OSHA) strongly recommends the installation of fire protection equipment. Wind farm operators having rigorous safety standards and programs in place, do adhere to these guidelines, and implement **fire protection measures**.

The common types of fire protection equipment for wind turbines include smoke, heat, and flame detectors, as well as fire suppression systems. When a fire is identified, a detection system can send information to a central alarm system that initiates the shutdown of the turbine's components. It can also activate a fire suppression system.

- [Will Fire Protection be Required on All Wind Turbines?](#)
- [Understanding Wind Turbine Fire Protection Options](#)
- [The Complete Guide to Wind Turbine Fire Protection](#)
- [Should You Opt In to Fire Suppression on Your Wind Turbines?](#)

## Wind Turbine Fire Suppression System

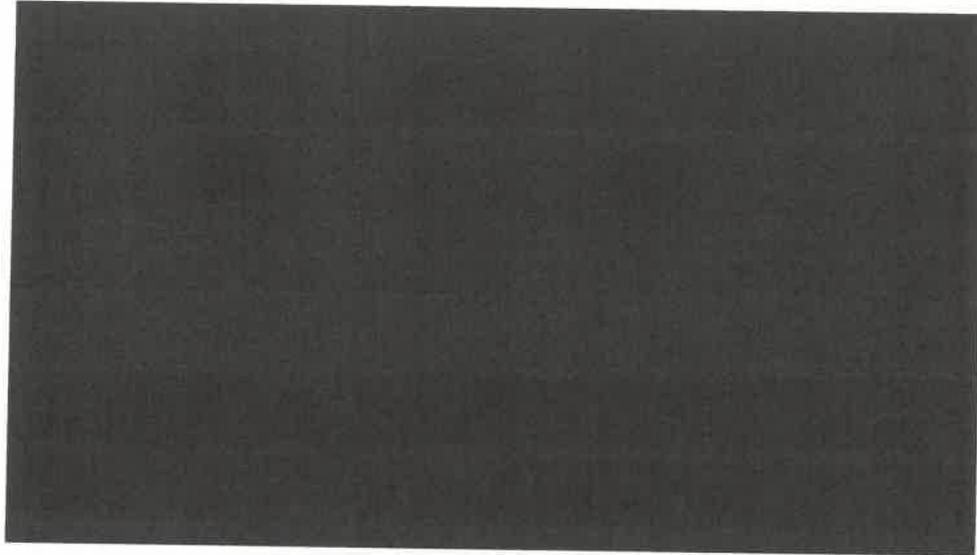
By adding **automatic fire suppression systems** within the wind turbine, you are able to protect components and areas that are prone to fire. This extra layer of security reduces the risk of having a catastrophic event. Once a fire is detected, the fire suppression system activates to suppress the fire before it can spread uncontrollably.

There are several types of fire suppression systems, of which some are better suited to protect wind turbines. Any type of water-based system, including sprinklers, water mist, and foam water are not ideal for protecting wind turbines due to the limited space, accessibility to water, and the damage caused to critical components. For onshore turbines, carbon dioxide (CO<sub>2</sub>) systems need an airtight environment to successfully suppress a fire. A benefit of CO<sub>2</sub> is that when discharging, no residue remains, and it will not harm electrical components. The disadvantage is that CO<sub>2</sub> has significant risks to humans if they are present during the discharge.

Aerosol-based fire suppression systems provide total flooding capabilities, gaseous matter, and ultra-fine solid particles. These systems require minimal maintenance and are considered environmentally friendly. They are generally considered safe for use in occupied spaces. The downside is that aerosol residue can damage sensitive electronics and critical components if left uncleaned.

The last option for wind turbine fire suppression systems is **clean agent** systems. These systems utilize suppression agents, like Chemours FM-200 and

FK-5-1-12, which are environmentally safe, leave no residue, does not damage equipment, and is safe for people in occupied spaces. The systems require minimal space for the clean agent cylinders and are less likely of a false discharge. Systems like **Firetrace**, do not require electricity and use fire detection tubing that is routed around fire-prone areas within the wind turbine. Once a fire is detected, the tubing will burst, activating the systems to release the clean agent to suppress the fire.



### Helpful Links

- [The Basics of Fire Suppression Systems Installation](#)
- [Case Study: Firetrace System Saves Wind Turbine from a Catastrophic Loss](#)

### In Summary

Without regulations or mandates, it is the discretion of wind farm owners to protect wind turbines from fire risks and damage. As replacement costs escalate, lost revenue from downtime, and reputational damage, protecting wind turbines from fire is crucial. Fire suppression systems offer the protection wind farm owners need. As noted, there a variety of different types of fire suppression systems. It is key to select a system that is the most compatible with the equipment and areas you are protecting.

[CONNECT WITH A WIND TURBINE FIRE SUPPRESSION EXPERT >](#)

### Other Helpful Links

- [Four Misconceptions About Wind Turbine Insurance](#)
- [A Discussion with Jatin Sharma on Wind Turbine Insurance and Fire Risk](#)

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# Will Fire Protection be Required on All Wind Turbines?

February 22, 2021 | By Tyler Scheviak

F-6

The number of wind turbine fires is increasing as the number of turbines installed increases. For example, a 100-turbine wind farm is on average ten times more likely to have a fire than a 10-turbine wind farm. This trend is affecting the reputation of the industry, hardening the insurance market, and has the potential to hurt the growth of the wind industry.

## Topics

- Renewable Energy

## What are Fire Regulations?

Fire regulations are common in many industries. Buildings and factories are a couple of examples. They establish a baseline of best practices to keep people safe from fire risks. However, fire regulations are much vaguer for wind turbines. Certain standards exist as guidelines (NFPA, CFPA, VDS), but ultimately it is up to the Authority Having Jurisdiction (AHJ) to decide what fire safety steps are required in most cases. Some AHJs have been proactive regarding wind turbine fire protection and have made detectors and/or fire suppression systems required. Others are leaving the bulk of fire protection up to the turbine manufacturers, developers, and owners.

## What Causes Something to be Regulated?

There can be several reasons why regulations increase. After fatal events, changes in legislation, investor demand, or an AHJ decides a regulation should be changed. In the case of wind turbines, about 1 in 2,000 catch on fire per year over their 20-year lifespan. If one of these fires were to cause a wildfire with a large amount of damage to people and property, fire regulation is almost guaranteed.

## Reasons Wind Turbine Fire Regulations May Increase in the Future

Fire regulations are expected to increase in the future due to several factors. We'll discuss the major trends below.

### Increasing reliance on wind energy

Some communities and businesses are heavily dependent on renewable energy. If an entire wind farm is down for a day, then meeting energy demands can be difficult. We saw this happen recently in [Texas](#). By preventing stoppages due to fire, wind farms have improved business continuity.

## Increase in the number of wind turbine fires

The rate of [wind turbine fires](#) has remained consistent at about 1 in 2,000 per year over a turbine's lifespan, meaning that a wind farm with 150 turbines will experience 1-2 fires over 20 years. As the number of wind farms increases, the number of fires is expected to increase. Each fire poses a threat to people, the environment, and local communities, so it is best to prevent them from occurring.

## Large insurance payouts due to wildfires

When an [insurance claim](#) is filed for a wind turbine fire, no party benefits. You must dedicate resources over weeks, or even months, to investigate the fire and perform mitigation efforts. After all of this, you may be surprised that your insurance policy doesn't cover the entire loss and your premium and deductible may rise.

## Hardened wind turbine insurance market

Because of the large payouts, premiums in renewables have increased by 20-30%. Even if your own company did not experience a fire, the insurers still had to pay out claims, and increase premiums across the board as a result.

# Examples of Fire Protection Methods and Regulations

## Fire Detection

### The Importance of Fire Detection in Wind Turbines

Fire detection is a crucial risk mitigation/safety component that is already implemented on many turbines. Because wind turbines run unmanned, it is important to detect when there is a fire and react accordingly.

### Examples of Fire Regulations

Fire detection regulation is often left up to local authorities. For example, both [France](#) and [Belgium](#) have decrees that require fire detection on turbines. Over the past few years, these countries started to require fire detectors in only new turbines. Now the scope of this requirement covers **all** wind turbines, both new and those already in the field.

## Fire Suppression

### Fire Suppression Systems Put Out Fires in a Few Seconds

Fire detectors may be able to detect a fire, but how do you put a fire out once it starts? That is why fire suppression systems are so important. These systems can activate once a fire is detected and ensure that the fire is put out in just a few seconds, often saving the turbine (and \$7-8 million expense that a total loss causes).

### Examples of Fire Suppression Requirements

While fire suppression systems provide more safety benefits than fire detectors, they are in just a few percent of wind turbines. The main reason for this is the cost difference compared to simple fire detectors. However, after a quick **cost-benefit analysis**, fire suppression systems make financial sense. Because fires start wildfires, harm people, and damage property, some authorities have required **fire suppression systems** in their jurisdiction. Examples are New Hampshire, USA and Ontario, Canada.

## Future-Proofing Your Wind Turbines

Everyone hurts when there is a wind turbine fire. By mandating risk mitigation measures like fire protection, wind turbines become safer and easier to insure. This gives owner/operators better rates, helps insurers lose less in claims payouts, and helps move the wind industry forward.

To ensure your turbines are ready for future regulations, it is best to evaluate fire detection and suppression systems now. Firetrace has industry-leading fire

detection and suppression systems that are safe for employees and electronics.

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# Understanding Wind Turbine Fire Protection Options

April 3, 2020 | By [Suzi Mein](#)

F-7

Wind turbines stand over 300 ft tall with each blade measuring over 100 ft long with blade speeds of up to 180 mph. Fire protection for these giant structures poses a variety of unique risks. Because there is no formal reporting process of reporting and recording fire incidents in wind turbines, it's hard to get an accurate count. However, in a 2015 report, **Towering Inferno**, completed by GCube, a clean energy insurance provider, cited 50 wind turbine fire incidents. While to some, this number is not very high, the cost implications are substantial. The total loss of a wind turbine costs at least \$4.5M, and that number is rising as the wind turbines are getting larger. In this post, we will explore hazards, ignition sources, and fire protection options for wind turbines.

## Topics

- [Renewable Energy](#)

## Hazards & Risk Factors

It is nearly impossible to put out a **wind turbine fire** using manual fire-fighting methods. The height of turbines, potential of the blade still rotating, and the remote locations many wind farms make them difficult, if not impossible, for local fire departments to battle. Combustible materials in the wind turbine are also risk factors. Composite materials are found in the blades, nacelle walls, and an estimated 235 gallons of lubricating oil and other highly combustible liquids that are held in the nacelle. These oils and liquids are used in the gearbox, yaw, hydraulic system, blade pitch change mechanism, oil pumps, mechanical brake, and oil-filled transformer. All that is needed is an ignition source to spark a fire.

## Ignition Sources

Common ignition sources are found in the nacelle and include electrical malfunction, hot surface ignition, and lightning strikes. When lightning protection systems are not installed or maintained, it puts the wind turbine at a higher risk of fire. Electrical malfunctions, faults, and arcs can happen in components found within the nacelle, while hot surfaces in the gearbox, generator, brake system, pumps, and transformer are all factors that can ignite a fire.

## Wind Turbine Fire Protection Options

As of today, fire protection standards for wind turbines are at a localized level, which could be by state, providence, city, or even municipality. There is no

mandated international standard. The most widely recognized recommendation is NFPA 850, which recommends practice for fire protection for electric generating plants and high voltage direct current converter stations.

When it comes to **wind turbine fire protection**, options do exist. Smoke, heat, and flame detectors, as well as **fire suppression systems**, can be installed on wind turbines. These various detectors can identify a fire during the early stage and send information to a central alarm system that will initiate a complete shutdown of the turbine's components and activate a fire suppression system. However, special consideration needs to be taken into account for onshore turbines that have air inlets/outlets and vents in the nacelle, which brings in dirt and dust from the outside. Any detectors need to be able to stand up to the harsh environment.

## Types of fire suppression systems

Adding a fire suppression system to a wind turbine provides a layer of fire protection. If you decide to **opt in to adding fire suppression systems**, several options are available (with varying levels of success).

### Water-based

Water-based fire suppression systems include sprinklers, water mist, and foam water. While these types of systems are ideal for certain applications, wind turbines are not one of them. The first challenge is the need for a water supply. Because of the remote locations, water is not widely available on the site and difficult to pump to the height of the turbines. Storing water in the nacelle is possible if using a water mist system and foam water systems, but space is still a challenge, and the systems require more intensive maintenance. Lastly, all water-based systems will have some level of damage to critical components within the nacelle, especially if a false discharge occurs..

### Carbon Dioxide (CO2)

The challenge in using **CO2** systems is the need for an airtight nacelle, which is not the case for onshore wind turbines. When activated in an airtight environment, these systems provide suppression within seconds after discharge and can penetrate inside components and equipment. The maintenance of gas-based systems is rather low and should be checked or monitored for the level of CO2 to ensure no leaks. When discharged, CO2 leaves no residue and does not adversely affect electrical components;

however, CO2 does pose significant risks to humans present during a discharge and requires extensive lock out tag out measures to ensure people safety while accessing the space.

## Aerosol-based

Aerosol-based fire suppression consists of very fine solid particles and gaseous matter and provides total flood protection. While the systems are relatively small, special consideration needs to be taken during the design with regards to the proximity to components within the nacelle. Aerosol-based systems are considered environmentally safe; however, they can leave a residue causing damage to sensitive electronics. A specific cleaning protocol should be followed post aerosol discharge to minimize damage from the residue. These systems are easy to service as they require minimal maintenance.

## Clean Agent

Automatic fire suppression systems using **clean agents**, like Chemours FM-200 and FK-5-1-12, are an ideal option to protect wind turbines. Little space is required for cylinders that contain the clean agent, detection tubing is easily routed around the specific areas within the wind turbine you are trying to protect, and the systems do not require electricity to operate. The systems are less prone to false activation, and clean agents are safe in occupied/confined spaces around people and do not damage equipment. No residue is left after a discharge of the clean agents; therefore, no clean-up is required. Completing annual inspections will ensure the systems are in proper working order.

## Conclusion

The International Association for Fire Safety Science **reported in 2014** that over 90% of wind turbine fires resulted in the total loss of the turbine, or the turbine had severe structural failure of its major components. With the costs rising of wind turbine replacements due to fires, it is more important than ever to protect them. Protecting turbines can be done by installing fire suppression systems to detect a fire as soon as it starts and then suppresses it to prevent the fire from spreading. There are many types and sizes of fire suppression systems, each working in a unique way. Keep in mind, selecting and designing the best system for your application is based on the equipment needing protection and the type of fire hazard.

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# HOW TO EVALUATE FIRE RISK AT WIND FARMS

Key steps wind farm operators should take to assess fire risk, protect lives, preserve assets, and save on costs

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# Summary

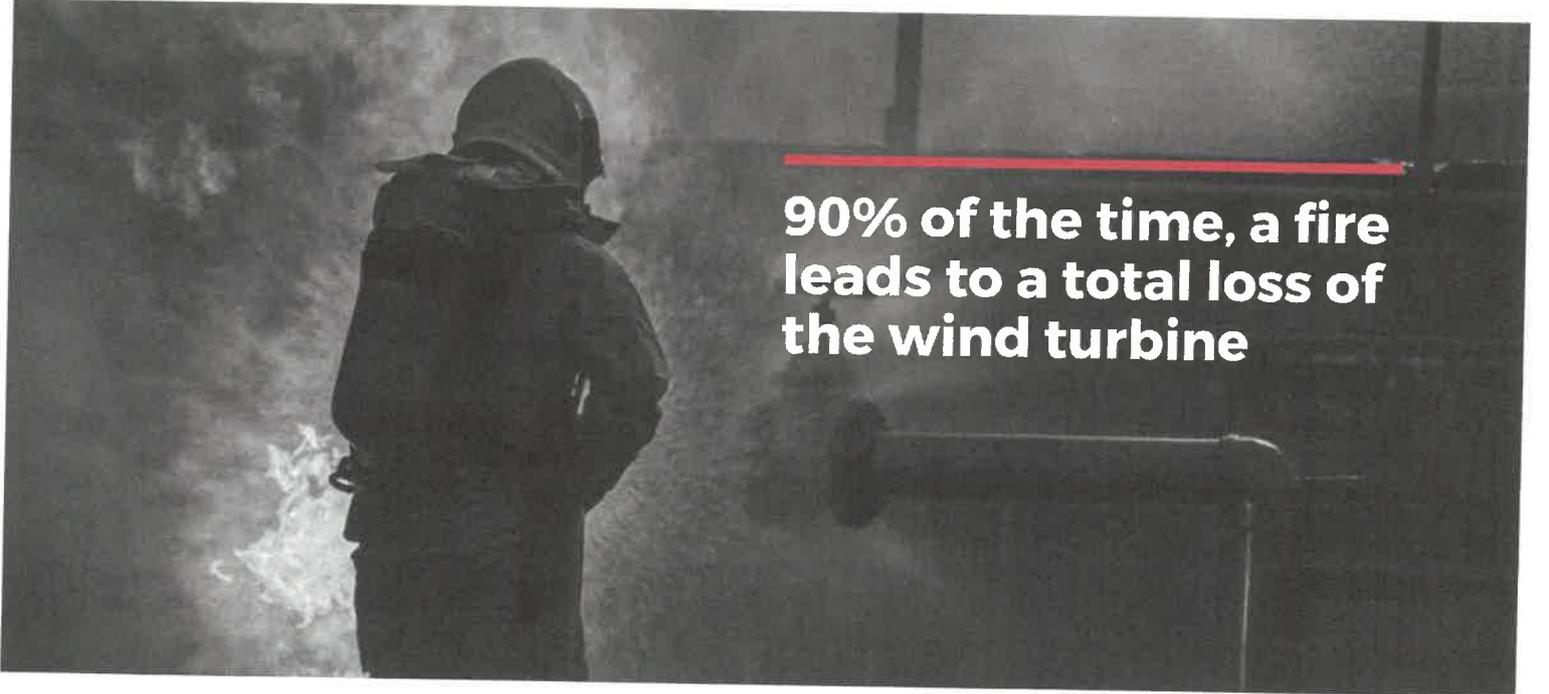
**Reducing the risk of injuries to personnel, as well as avoiding fatalities - in addition to limiting damage to assets - should be a priority for all wind farm operators.**

In order to achieve these objectives, performing an effective fire risk assessment (FRA) is crucial.

Conducting and acting on an FRA will also increase the probability of saving on costs incurred due to turbines being damaged or destroyed by fire (90% of the time, a fire leads to a total loss of the wind turbine). In addition to the cost of repairing or replacing a turbine (which can be as high as \$9 million), it can also mean 12-18 months of revenue is lost while a turbine is being recommissioned.

An FRA could also reduce the likelihood of wildfires occurring from a turbine fire, which can have a devastating effect on the surrounding area, including the local community.

However, it is worrisome that very few wind farm operators traditionally think to conduct properly structured FRAs, unless they have been previously impacted by fire. This is partly due to the fact there is no requirement to conduct an FRA. In addition, third-party independent service providers do not, generally speaking, include FRAs in their scope of services.



**90% of the time, a fire leads to a total loss of the wind turbine**

In order to address this issue, this report explains why it's important to conduct an FRA, and sets out the key steps you should take in order to conduct an FRA effectively.

In addition, the report details how you should use the results of an FRA to ensure the maximum benefit for the organization. The report also explains how your organization will benefit from a professionally managed FRA.

Finally, the report explores what technology can be used to minimize fire risk, and what constitutes best practice when conducting an FRA.

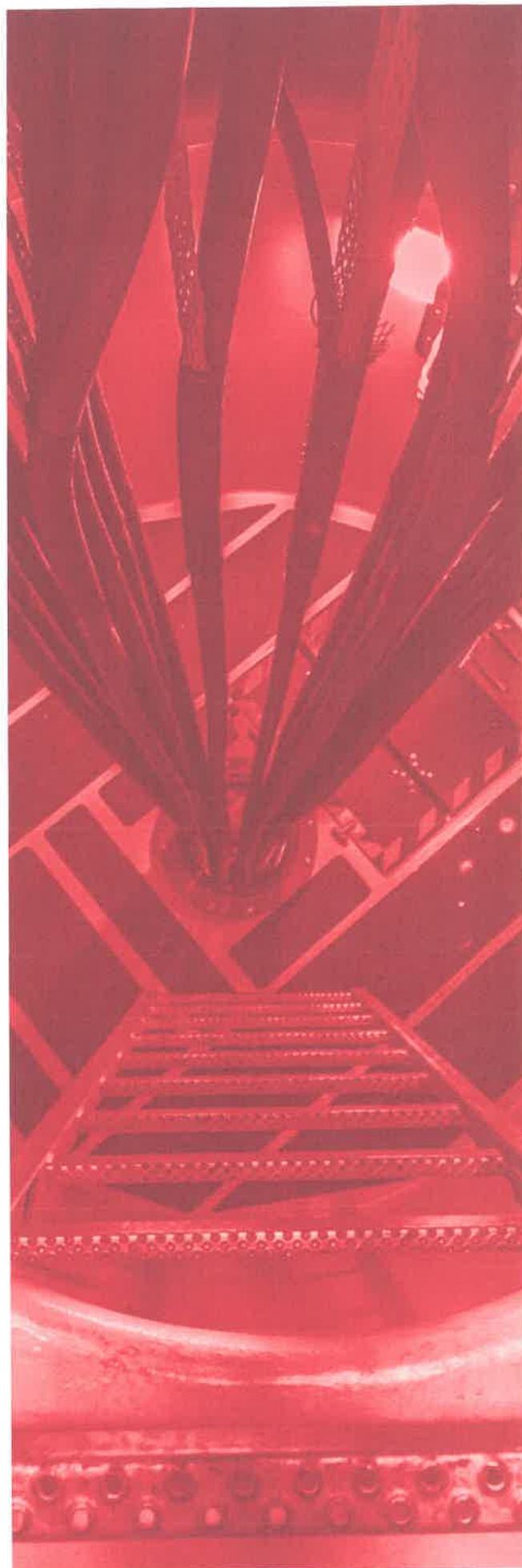
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Firetrace International would like to thank the following individuals for their contributions to this report:

- **Angela Krcmar**, Global Sales Manager - Wind, Firetrace International
- **JP Conkwright**, Assistant Professor, Fire and Safety, Eastern Kentucky University

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SUMMARY



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# Why it's important to evaluate wind farm fire risk

**It is vital that wind farm operators evaluate the fire risks that are present on site.**

## **Effective fire risk assessments will:**

- Protect personnel working on site by reducing the probability of fire events occurring
- Increase the level of protection for wind farm assets by reducing the risk of wind turbines being damaged or destroyed by fire
- Save on the cost of repairing or replacing a damaged or destroyed turbine (replacing an individual turbine damaged by fire is becoming increasingly expensive and can now cost up to \$9 million) with 12-18 months of expected revenue loss and down time to get replacement parts
- Potentially reduce the amount your business pays for insurance (insurers could potentially adjust rates if wind farm operators include fire suppression measures)
- Reduce the risk of causing wildfires in the surrounding area
- Boost the reputation of your company from an operations perspective
- Help to bolster the reputation of the wind industry in general

**Replacing an individual turbine damaged by fire can now cost up to \$9 million**

It's important to note that simply performing one fire risk assessment does not constitute effective fire risk management. Assessments should be updated at regular intervals in order to determine whether the risks posed have changed.

Angela Krcmar, global sales manager – wind at Firetrace International, says: “If the fleet has been in operation for five years plus, the risk factors could be greater as the age of the fleet goes up – if you have a fleet that is five, ten or fifteen years old, the risks are different than if you have a brand-new fleet.”

Krcmar adds that an aging fleet has an increased risk of fire due to its extended use, while new fleets also pose a risk when they are being tested in the market.

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**If you have a fleet that is five, ten or fifteen years old, the risks are different than if you have a brand-new fleet**

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WHY IT'S IMPORTANT TO EVALUATE WIND FARM FIRE RISK



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# Why are so few wind farm operators conducting FRAs?

**Surprisingly, despite the numerous benefits of conducting fire risk assessments, very few wind plant operators are doing so in a formal, structured way.**

JP Conkwright, assistant professor of fire protection and safety engineering technology at Eastern Kentucky University, says there seems to be little evidence that wind farm operators are conducting “holistic fire risk assessments following some type of recognized standard”.

Why is this? There is a belief among some experts that some wind farm operators do not conduct fire risk assessments because they feel having insurance means the assessments are unnecessary. In addition, other reasons for the lack of FRAs may include concerns about revenue loss due to down time as well as a lack of resources caused by the Covid pandemic.

However, the National Fire Protection Association (NFPA)'s guidance on recommended practice for fire protection for electric generating plants - known as the NFPA 850 - encourages

the development of a “fire protection design process” and a “fire risk control program” among other measures.

Another possible explanation for unwillingness to conduct FRAs is that wind farm operators greatly underestimate the cost of replacing a wind turbine damaged by fire.

Conkwright points out that, for example, the cost of replacing only one damaged turbine can be more expensive than anticipated because it is not possible to achieve the “economies of scale” that are gained when, say, adapting roads and building bridges to transport the turbines needed for an entire wind farm.

Crane costs are particularly relevant in this context. Krcmar notes that “crane costs are significant and availability is also an issue in the current climate”.

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# How to effectively evaluate fire risk

In order to conduct an effective wind farm fire risk assessment, it is worth consulting the NFPA's guidance on evaluation of fire risk assessments, specifically its '551' guide.

In summary, when conducting an assessment, key considerations include:

- **How will the FRA evaluate the likelihood and consequences of scenarios?**

This should be based on past experience (for example, statistics) for well-understood events or on available knowledge for less-understood events where uncertainty and variability are high. The evaluation of consequences may be based on expert knowledge (risk indices, for example) or probabilistic modeling (for example, using a life safety tree).

- **What is the scope of the FRA?**

It could involve an assessment of one fire risk protection concept or system (a single-system assessment) or the overall level of risk (a multisystem assessment). As highlighted in the NFPA's 551 guide, multisystem assessments often require more sophisticated methods in which the assessment is based on the overall impact of the availability, reliability, and operation of both passive systems - which prevent the spread of fire via fire-resistance rated walls or floors, for example - and active fire protection systems, such as smoke detectors and fixed fire suppression systems.

- **What fire scenarios will the FRA cover?**

Factors to consider in the FRA include:

- Fire ignition***

*Would prevention education reduce the probability of the event occurring and help to avoid the consequential risks?*

- Fire growth***

*Would fire protection systems such as fixed fire suppression systems help to contain the fire? Are the fire control systems reliable enough and effective enough to reduce the risk? The more reliable and effective the fire control systems are, the more the risk will be reduced.*

- Failure of fire department to respond***

*How effective is the notification procedure and are the fire department's resources adequate?*

- **Who is the intended audience?**

The FRA output and the FRA method selected should be consistent with the knowledge and needs of the intended audience.

- **What are the FRA teams' qualifications?**

The qualifications of the team performing the FRA should be addressed in the evaluation of the FRA. Expertise and experience in understanding the risk problem and implementing an appropriate type of FRA should be considered. Consider engaging a consultant, such as insurance loss adjusters and fire risk investigators specialized in wind.

- **Will the FRA utilize a 'Fire Safety Concepts Tree'?**

The NFPA has developed a 'Fire Safety Concepts Tree' that shows relationships between fire prevention and fire damage control strategies that could help to identify gaps in fire protection.

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# How to use the results of a fire risk assessment

Once the FRA has been completed, how should the results be used?

## The FRA should be shared with:

### 1. Colleagues responsible for personnel safety:

It should be noted that some fire risk assessments fail to address all potential 'fuel sources' and thus it is important to consult safety professionals. Conkwright explains that some FRAs do not cover significant sources of fire such as cable installation, which has resulted in major fires in turbines.

### 2. Your operations team:

The findings of the FRA should be shared with your operations team, particularly those responsible for maintaining the assets as standards of maintenance can impact on fire risk.

### 3. Your finance team:

The FRA could potentially have an impact on the organization's budgeting so it is beneficial if the results are shared with the finance team.

### 4. Colleagues responsible for capital expenditure:

This is crucial because, as Krcmar points out, "the team responsible for the capex for a new development is different from the team responsible for the operations of the fleet once it's online - it's important to make connections with those two teams because there is typically a disconnect".

**5. External providers of finance:**

There are some small and medium-sized wind plant operators that are financed by organizations that may have gaps in their knowledge when it comes to wind farms' fire risk, says Conkwright.

**6. Colleagues responsible for negotiating insurance cover for the asset:**

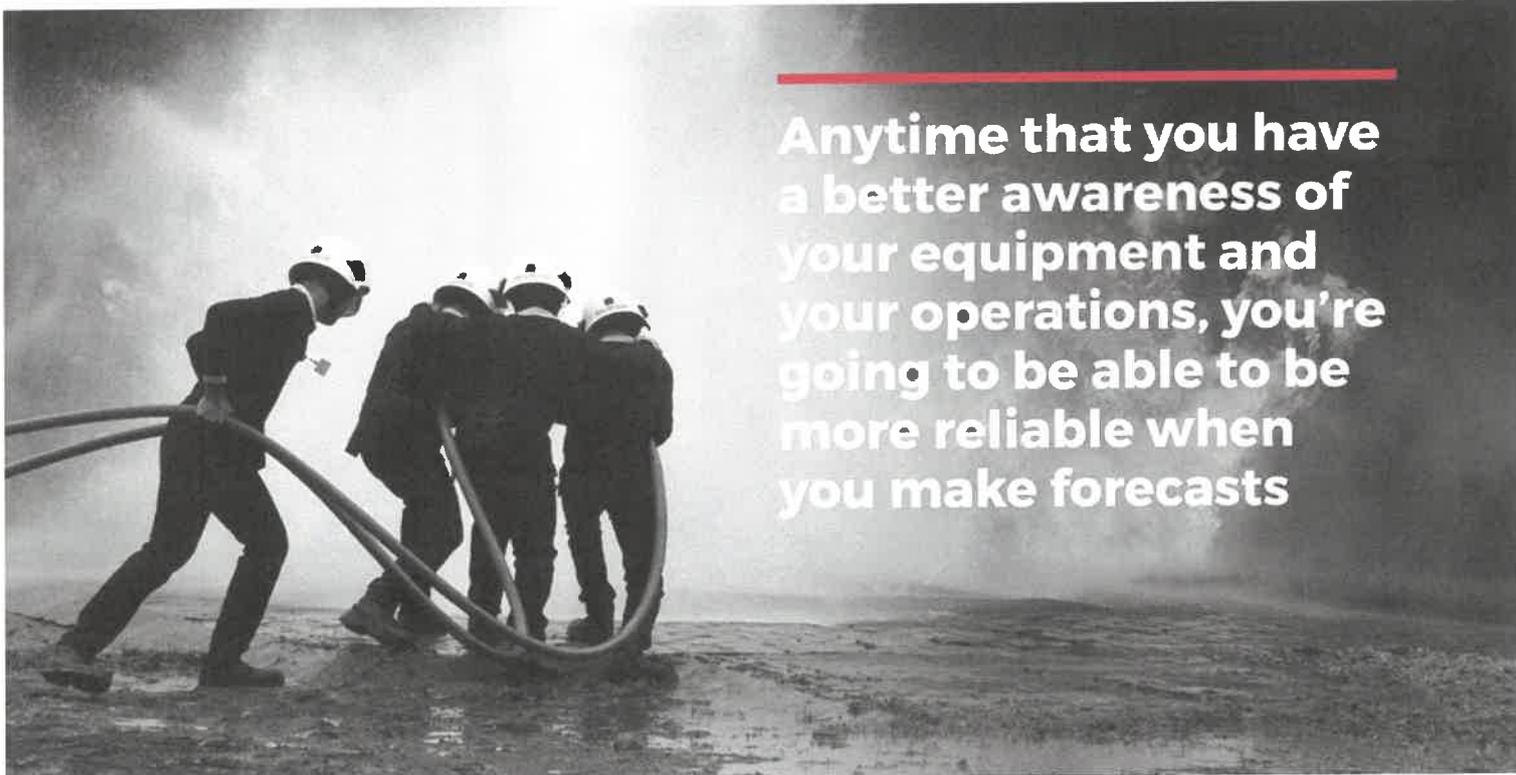
An assessment of the level of onsite fire risk could be an important consideration when obtaining insurance coverage.

**7. Your loss adjuster or insurance provider:**

It may be necessary to conduct an FRA following a fire event or in connection with an insurance renewal so, in such instances, it could be beneficial to share the results with your loss adjuster and/or insurer.

**8. The local fire department:**

A knowledge of specific fire risks at a particular site will help first responders tackle any fire that does break out.



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**Anytime that you have a better awareness of your equipment and your operations, you're going to be able to be more reliable when you make forecasts**

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# How your organization will benefit from a fire risk assessment

**An effective FRA could make it less likely that life is endangered by a fire at your wind farm and could also reduce the risk of the surrounding area being impacted by fire.**

In addition, you could also make it less likely that your assets are damaged or destroyed by fire.

Krcmar says when conducting an FRA, it's important to consider whether you are "making your project generally safer for your personnel and the surrounding community and whether you are making your assets safer".

Meanwhile, any steps you take to better understand your assets and the associated risks, will ultimately mean you will be able to make your wind farm more profitable, Conkwright says.

"Anytime that you have a better awareness of your equipment and your operations, you're going to be able to be more reliable when you make forecasts - reliability and variability are very

important, so anytime you get rid of that variability and increase your reliability, you can be more profitable," Conkwright explains.

He adds that another benefit of FRAs is that they enable wind farm operators to better understand their turbines and be more resilient in the sense that if they are aware of potential risks, they are then better able to monitor them.

In addition, this means you are better able to anticipate fire events, which means you are in a better position to respond to them.

"Knowing about your risk up front, instead of being surprised by it, means you can respond really quickly if there is a problem," Conkwright says.

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# What technology do you need to minimize fire risk?

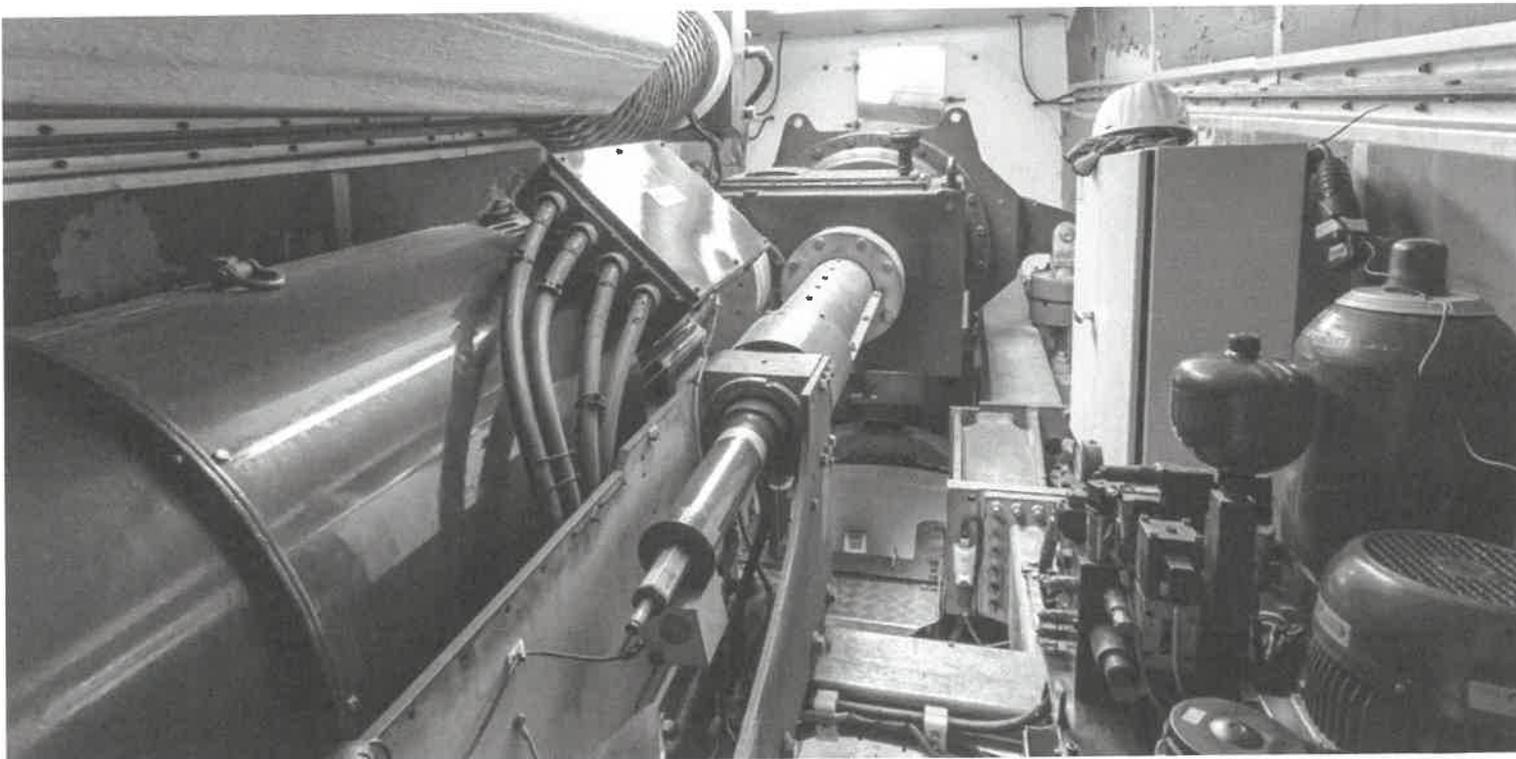
**In addition to fire detection and fire suppression systems, it is also recommended that wind farms have lightning detection and arc detection systems.**

With regard to fire detection and suppression systems, there needs to be careful consideration given to where they are positioned. Krcmar points out that detection and suppression systems need to be located near the potential ignition sources so steps need to be taken to identify where they are exactly.

She adds that dust can also impact on internal operations of wind farms. It is important to work with a detection and suppression system that takes the dust

and debris into consideration and select a solution that is the most reliable for this environment.

Conkwright says that the use of arc detection and ground fault detection is becoming more prevalent in wind farms. However, he adds that one of the benefits of an effective fire risk assessment is that it can help you determine what type of detection is best suited to each type of ignition risk.



## Checklist: Best practice in fire risk assessment

**So, what are the key steps you should take in order to perform an effective fire risk assessment? Here is a checklist:**

### **1. Consult a wind farm fire risk expert**

Expertise and experience in understanding wind farm fire risks will ensure that the appropriate type of FRA is conducted. Effective fire risk assessment is a unique skill. It is especially advantageous to work with a consultant with an understanding of both turbine operations and the science of fire protection. “There are fire engineers with little or no experience of the wind industry and there are wind industry professionals who don’t know about fire protection engineering,” says Conkwright. A wind fire risk expert will be able to assess the risks posed to your assets and the surrounding area based on experience gained at other sites.



**There are fire engineers with little or no experience of the wind industry...**

**...and there are wind industry professionals who don't know about fire protection engineering**



**2. Develop a framework for communications between specialists in turbine operations and fire risk assessment professionals**

Often these two groups struggle to communicate effectively so frameworks for communication should be formalized. Bring experts from both sides together and then use a fire safety concepts tree, for example, as a basis for addressing the issue. For guidance on developing a fire safety concepts tree, it is worth consulting the NFPA 550: Guide to the Fire Safety Concepts Tree.

**3. Determine what will be the most effective method of fire risk assessment**

Decide what type of assessment will work best for your site - for example, 60 to 70 percent of the FRA could include generic elements, but the remainder may need to be tailored to meet the requirements of the specific site.

**4. Consider how the type of turbine being used and the location of the turbine will impact on the level of fire risk**

Ignition sources will vary depending on the type of turbine being used, while the location of the turbine will also be a factor.

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# Conclusion

**In order to effectively evaluate fire risk, wind farm operators should consult industry experts on the best approach.**

For example, the National Fire Protection Association has issued useful guidance on how to conduct FRAs.

Key considerations include how the FRA will evaluate the likelihood of different scenarios, what will be its scope and who the intended audience will be.

It's also important that the findings of the FRA are shared with and acted upon by a range of stakeholders including colleagues responsible for safety, capital expenditure, and negotiating insurance cover. The findings should also be made known to the operations team, the finance team, external finance providers and the local fire department. It may also be beneficial to share the findings with your loss adjuster and insurance provider.

In addition to using fire detection and suppression systems, it is also recommended that lightning detection systems are implemented at wind plants. Meanwhile, considerations should be given including multiple detection methods, reliable spot detection, arc detection and ground fault detection.

Following these recommendations could reduce the risk of injuries to personnel – as well as fatalities – at your wind plant. In addition, you could also limit the danger of spreading wildfires in the surrounding area as well limiting the risk of incurring substantial costs due to turbines being damaged by fire.

Would you like to talk about the risks in this report?  
How about your approach to fire risk in your portfolio?

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## HOW TO ENHANCE WIND TURBINE FIRE SAFETY?

Improving fire protection for wind energy installations requires a comprehensive approach combining prevention, early detection, and effective suppression systems. Strategic measures include implementing advanced thermal monitoring, regular electrical system inspections, specialized fire detection sensors, and automated suppression systems designed for nacelle conditions. Proper staff training, adherence to international safety standards, and collaboration with fire safety experts significantly reduce fire incidents and their potential consequences. With appropriate protective technology, wind turbines can maintain optimal operational safety throughout their service life.

### WHAT CAUSES WIND TURBINE FIRES?

Wind turbine fires typically originate from several key sources, with electrical malfunctions leading the causes at approximately 43% of all incidents. These electrical failures often occur in converter cabinets, capacitors, and



F-9

transformers located in the nacelle. Lightning strikes account for about 23% of fire incidents, particularly affecting blade tips and control systems despite lightning protection systems.

Mechanical failures represent another significant fire risk (18% of incidents), primarily from overheating bearings, gearboxes operating beyond temperature thresholds, and brake system malfunctions during high winds. Hydraulic systems contribute to approximately 10% of fires when pressurized oil leaks contact hot surfaces.

Poor maintenance practices and human error during service operations account for the remaining incidents. Analysis shows that turbines aged 5-10 years face heightened risk as components wear while maintenance intervals sometimes lengthen, creating optimal conditions for fire ignition.

## HOW COMMON ARE WIND TURBINE FIRES?

Fire incidents in wind turbines, while relatively rare, represent a significant operational concern. Industry data indicates that approximately 0.3-0.5% of turbines experience fire events during their operational lifetime. While this percentage appears small, it translates to around 120-170 reported turbine fires annually worldwide based on current global installations.

Compared to conventional power generation facilities, wind turbines present unique fire risk factors due to their height, remote locations, and concentrated electrical and mechanical systems in nacelles. Onshore turbines typically experience higher fire incidence rates than offshore installations, largely due to different maintenance protocols and environmental exposures.

Several factors influence fire occurrence rates across regions and turbine types:

- Larger turbines (>3MW) show higher fire vulnerability due to increased electrical loads
- Turbines in areas with frequent lightning activity face elevated risks
- Units operating in extreme conditions (very hot or cold climates) experience higher fire incidence
- Maintenance frequency significantly impacts fire occurrence rates

## WHAT ARE THE SAFETY RISKS ASSOCIATED WITH WIND TURBINE FIRES?

Wind turbine fires create cascading safety concerns that extend well beyond the immediate structure. For maintenance personnel, nacelle fires present life-threatening situations due to limited escape routes from heights of 80-120 meters. Emergency evacuation often depends on specialized equipment that may be compromised during fire events.

Environmental impacts include potential soil contamination from burning composite materials, lubricants, and hydraulic fluids. A single turbine fire can release harmful particulates across substantial areas, particularly concerning in ecologically sensitive regions. Furthermore, burning debris can ignite vegetation fires in dry conditions, potentially affecting several square kilometers.

Communities near wind farms face risks from falling debris, with burning fragments documented traveling up to 500 meters from turbine bases. The financial implications are equally severe – a catastrophic turbine fire typically results in:

- Total asset loss (€2-4 million per modern turbine)
- Revenue disruption lasting 6-12 months
- Potential grid stability issues in regions dependent on wind generation
- Insurance premium increases across entire wind farm operations

## HOW CAN WIND TURBINE FIRES BE DETECTED EARLY?

Early detection technologies significantly reduce fire damage potential by identifying developing threats before catastrophic failure. Advanced thermal imaging systems installed in critical areas like converter cabinets, transformers, and gearboxes can detect abnormal temperature increases that precede ignition, often providing alerts hours before visible fire occurs.

Specialized smoke detection systems designed for the unique airflow patterns within nacelles offer another effective detection layer. These systems must withstand vibration, temperature fluctuations, and dust

without triggering false alarms. Spark detection technology focusing on electrical cabinets can identify arcing events that typically precede electrical fires.

AI-powered monitoring solutions represent the latest advancement in fire detection technology. These systems:

- Analyze patterns from multiple sensor inputs simultaneously
- Learn normal operation parameters for specific turbine models
- Distinguish between routine temperature variations and concerning trends
- Reduce false alarms by up to 87% compared to traditional threshold systems

Salgrom's detection technologies integrate seamlessly with SCADA systems, enabling automatic notification of operators via multiple communication channels when fire risks are identified.

## WHAT FIRE SUPPRESSION SYSTEMS WORK BEST FOR WIND TURBINES?

Aerosol-based fire suppression systems offer exceptional effectiveness for wind turbine nacelles. These systems discharge potassium-based aerosols that interrupt the chemical chain reaction of combustion while providing cooling effects. Their compact, lightweight design makes them ideal for the space constraints of nacelle environments. [Salgrom's Hex-Max™](#) and [Hex™](#) aerosol systems deliver powerful suppression capabilities with minimal installation requirements and low maintenance needs.

Gas-based systems using clean agents like HFC-227ea or FK-5-1-12 provide an alternative approach, effectively suppressing fires without leaving residue on sensitive electrical components. However, they require sealed compartments to maintain concentration levels and typically involve higher installation costs.

Water mist solutions create fine water droplets that efficiently absorb heat and displace oxygen, though their effectiveness can be limited in the electrical fire scenarios common in turbines. Hybrid systems combining

detection and suppression technologies often provide the most comprehensive protection by addressing different fire types across various turbine components.

The optimal approach frequently involves targeted protection strategies for different areas:

- Electrical cabinets: Aerosol or clean agent systems
- Hydraulic systems: Specialized powder agents
- Mechanical components: Combination approaches

## **HOW DOES PROPER MAINTENANCE REDUCE WIND TURBINE FIRE RISKS?**

Regular preventive maintenance forms the foundation of effective fire risk management in wind turbines. Comprehensive electrical system inspections should occur quarterly, focusing on connection integrity, insulation resistance testing, and thermal imaging of high-risk components. Loose connections causing increased resistance often develop hotspots before ignition, making infrared scanning a valuable early detection method.

Hydraulic system checks require particular attention to hose integrity, fitting security, and potential leakage points near hot surfaces. Oil analysis can reveal contamination levels that accelerate component wear leading to overheating. Mechanical friction points, particularly in bearing assemblies and gearboxes, benefit from vibration analysis that can identify developing issues before they generate excessive heat.

Maintenance protocols that significantly reduce fire incidents include:

- Scheduled replacement of critical components before end-of-life
- Regular cleaning of electrical cabinets to remove combustible dust
- Verification of lightning protection system integrity following storms
- Documentation of near-miss incidents to identify patterns requiring intervention

## WHAT STANDARDS AND REGULATIONS GOVERN WIND TURBINE FIRE SAFETY?

Several international standards provide frameworks for wind turbine fire safety implementation. IEC 61400-1 establishes general design requirements including fire safety considerations, while NFPA 850 offers specific recommendations for fire protection in electric generating plants including wind turbines. The EN 50308 standard addresses protective measures for wind turbines with particular attention to fire risks.

Certification requirements typically include risk assessments documenting potential fire scenarios and corresponding mitigation strategies. Many insurance providers mandate specific fire protection measures exceeding minimum regulatory requirements. Compliance monitoring increasingly involves remote diagnostic capabilities with automated reporting to verification authorities.

Regulatory frameworks continue evolving as the industry responds to incidents and technological developments. Recent trends include:

- More prescriptive requirements for detection system response times
- Mandatory suppression systems in turbines near vulnerable areas
- Enhanced documentation requirements for maintenance procedures
- Specific training certifications for personnel working with fire systems

## HOW SHOULD WIND FARM OPERATORS PREPARE FOR FIRE EMERGENCIES?

Comprehensive emergency response planning represents a critical component of wind farm fire safety. Effective plans include detailed procedures for various fire scenarios, clearly defined roles and responsibilities, and specific coordination protocols with local fire services. Important documentation should outline turbine access points, fire system controls, and emergency shutdown procedures.

Staff training requirements must address both prevention and response aspects. Regular drills should test evacuation procedures from nacelle heights using emergency descent devices. Coordination with local fire departments is essential, including familiarization visits to help services understand the unique challenges of turbine fires.

Post-incident investigation protocols should establish systematic procedures for documenting evidence, analyzing root causes, and implementing corrective measures. The most effective emergency preparations include:

- Regular testing of all fire detection and suppression systems
- Maintenance of emergency equipment including descent devices
- Updated contact information for all stakeholders
- Clear communication channels for emergency notifications

## **ESSENTIAL WIND TURBINE FIRE SAFETY INSIGHTS TO REMEMBER**

Protecting wind energy assets from fire hazards requires an integrated approach combining prevention, early detection, and effective suppression. The most successful fire safety strategies implement layered protection—addressing electrical, mechanical, and environmental fire risks simultaneously rather than treating each in isolation.

Customized solutions based on specific turbine designs yield significantly better outcomes than generic approaches. Modern turbines with varying nacelle configurations, power capacities, and component layouts require tailored protection strategies addressing their unique risk profiles.

Staff training represents a critical yet sometimes overlooked component of fire safety programs. Technicians who understand fire risks during maintenance procedures help prevent incidents through heightened awareness and proper work methods.

Continuous improvement driven by incident data analysis enables constant refinement of protection strategies. Leading wind farm operators maintain comprehensive databases of fire incidents, near misses, and system activations to identify trends and improvement opportunities.





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# THE COMPLETE GUIDE TO WIND TURBINE FIRE PROTECTION

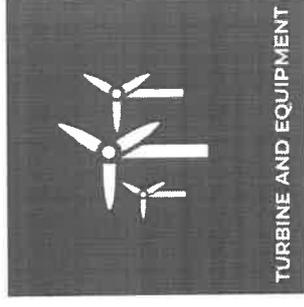
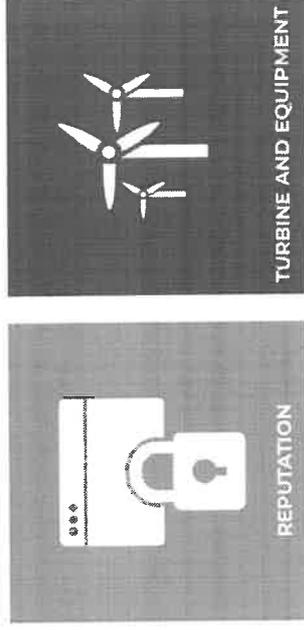
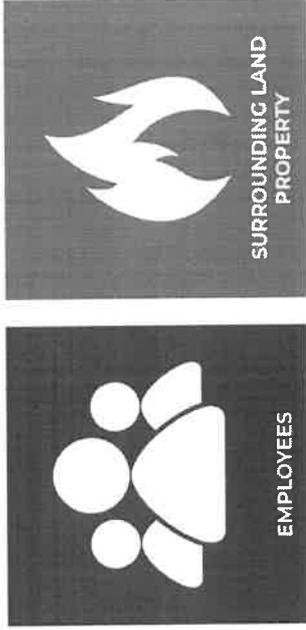
Assessing Risk | Types of Fire Protection Systems | ROI Calculation

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## ASSESSING RISK

To understand whether installing fire suppression systems in wind turbines is a practical decision for your business, you need to assess four factors:

- The likelihood a wind turbine will catch fire
- The cost of a fire in a wind turbine
- The cost of protection using one or more fire suppression systems
- The ability to prevent an increase in insurance rates at next renewal for mitigating fire risk



## FREQUENCY

Several different authorities have reported estimates of the annual rate at which wind turbines catch fire. These include:

- 1 in 6,000 (GCube Insurance, 2015)
- 1 in 1,710 (International Association for Fire Safety Science, 2014)
- 1 in 10,000 (Fire Protection Engineering Magazine, 2019)
- 1 in 2,000 (Wind Power Engineering Magazine, 2020)

For the purpose of this report, we will use the Wind Power Engineering figure, because it is the most recently published.

With wind turbines catching fire at a rate of 1 in 2,000 each year, a typical wind farm with 150 turbines will experience 1-2 fires during an operating span of 20 years.

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*In other terms, the average turbine has a **1 in 100 chance of catching fire** over an expected 20-year life.*

## **COST OF A FIRE**

The cost of a wind turbine fire can vary significantly due to a number of factors, including:

- The size and output of the turbine affected
- Extent of the damage and availability of replacement parts
- Whether or not parts can be salvaged
- If the fire spreads to nearby equipment or vegetation
- If required to temporarily shut down the entire wind farm or complete a root cause analysis



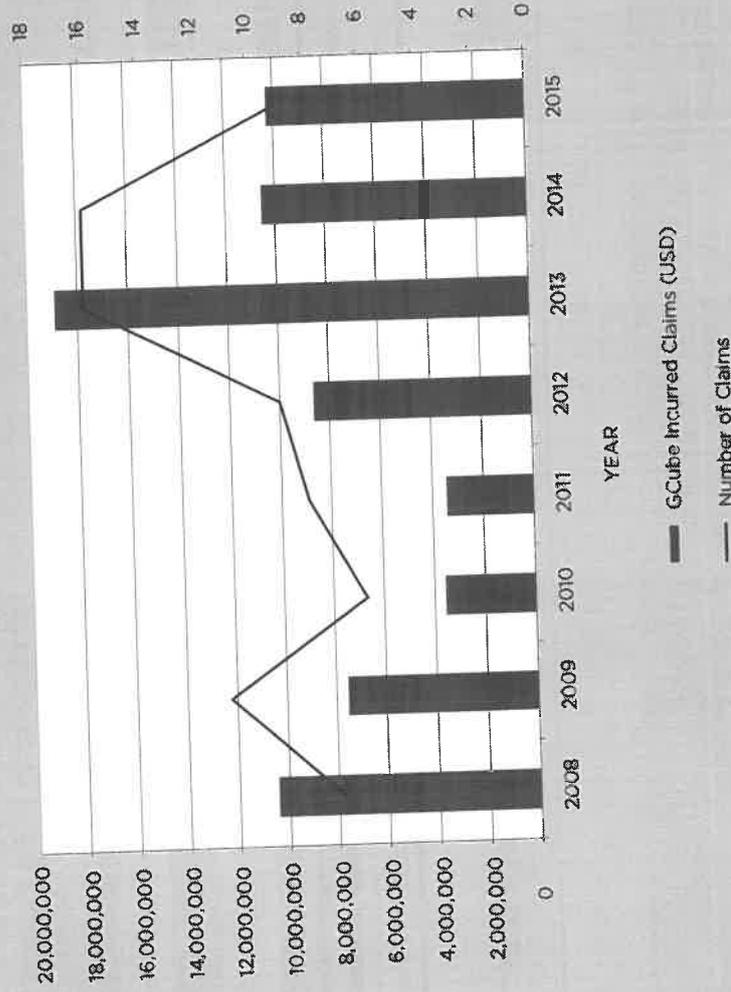
## FIRE CLAIMS 2008 - 2015

Between 2008 and 2015, the total amount in fire related damages paid by GCube insurance fluctuated significantly from less than \$4M in 2011 to over \$18M in 2013.

*In 2015, GCube estimated the average wind turbine fire costs \$4.5M.*

GCube estimates that the average wind turbine fire costs \$4.5M. Most wind turbine fires originate in the nacelle, making them extremely difficult to fight. Nacelle fires typically result in a total loss of the turbine.

*More recent estimates of wind turbine fires put the average cost around \$7-8M.*



Source: GCube December 2015 Report - Towering Inferno: Global Trends in Wind Turbine Downtime Events

## TYPES OF PROTECTION

Several different technologies can be used for fire protection in wind turbines. These include fire detection, arc flash detection, condition monitoring systems, and gaseous fire suppression systems. Most technologies focus on fire prevention. Only fire suppression systems, like those offered by Firetrace, can mitigate fire damage once a fire has started.

Firetrace systems target specific ignition sources in the wind turbine. This allows a flexible, modular approach to fire protection that can be customized for different turbine makes and models.

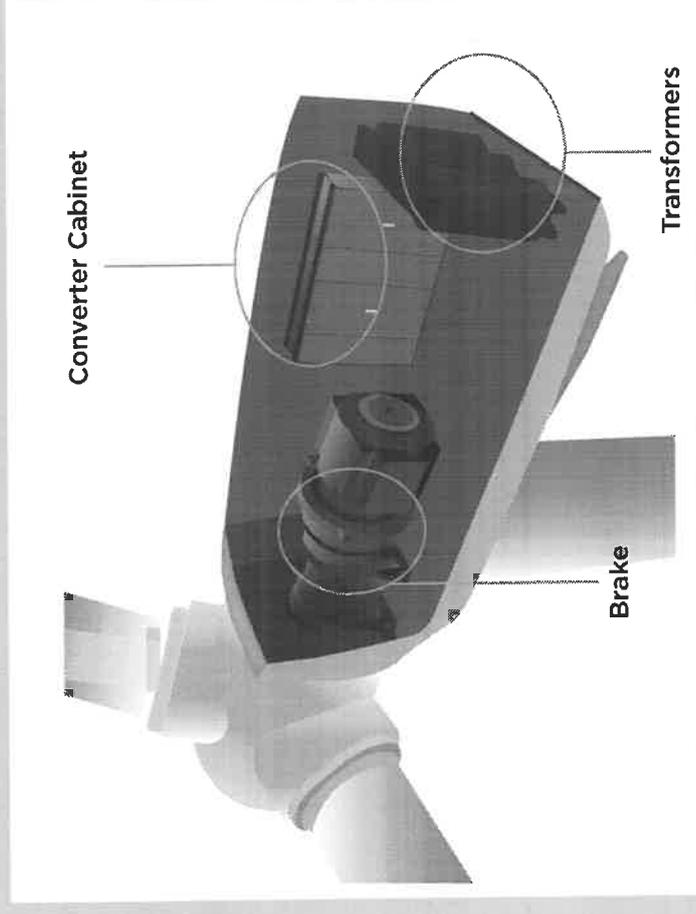


## IGNITION SOURCES

Broadly speaking, there are three primary ignition sources – or areas of risk – in a typical wind turbine:

- The converter and capacitor cabinets in the nacelle
- The transformer
- The nacelle brake area
- The hydraulic area is sometimes, but not often, considered a fourth ignition source

Of the three ignition sources in a wind turbine, most fires start in the converter cabinet or capacitor cabinet, located in the nacelle. According to Renewable Energy Loss Adjusters (RELA), electrical faults are the leading cause of fires: “This involves anything from short circuit, overloading, cable failure, and crimping failure to generator failure.”



# COMMON APPLICATIONS OF FIRE SUPPRESSION SYSTEMS

## CONVERTER AND CAPACITOR CABINET PROTECTION

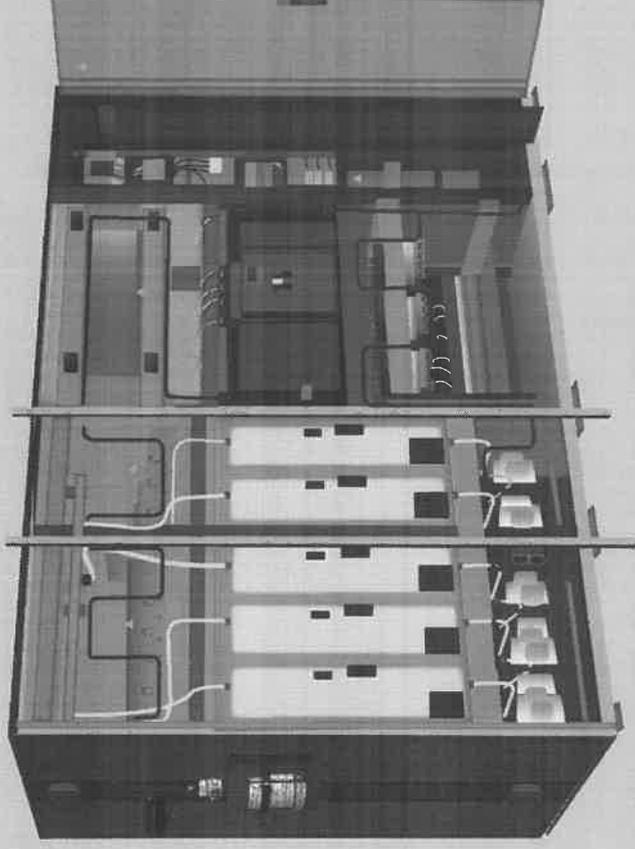
Because most fires start in the converter cabinet or capacitor cabinet, most wind turbine owners protect these areas first. Generally, both cabinets can be protected using a single Firetrace system. This is made possible by the design of the Direct Low Pressure (DLP) system, with flexible detection tubing that can be routed throughout the bank of cabinets. Suppression gas is delivered directly through the tubing.

## NACELLE BRAKE AREA PROTECTION

The nacelle brake area is also relatively straightforward to protect in most wind turbines. Firetrace recommends an Indirect Low Pressure (ILP) system for nacelle brake area protection. This system also detects fires using flexible detection tubing, but it delivers suppression gas through separate nozzles.

## TRANSFORMER PROTECTION

The transformer area, which is larger, may require a more robust system with multiple cylinders to ensure suppression agent effectiveness.



When installing a direct low pressure system on a capacitor cabinet or converter cabinet, route the flexible detection tubing around all possible ignition sources.

## **COSTS OF FIRE SUPPRESSION SYSTEMS**

Firetrace systems are available to purchase directly from leading wind turbine manufacturers. This allows project construction capital to be used toward the installation of fire suppression systems for new wind projects. Aftermarket installations are also feasible due to the simple design of the systems. Firetrace recommends budgeting \$5,000 per turbine for aftermarket installations as an initial estimate.

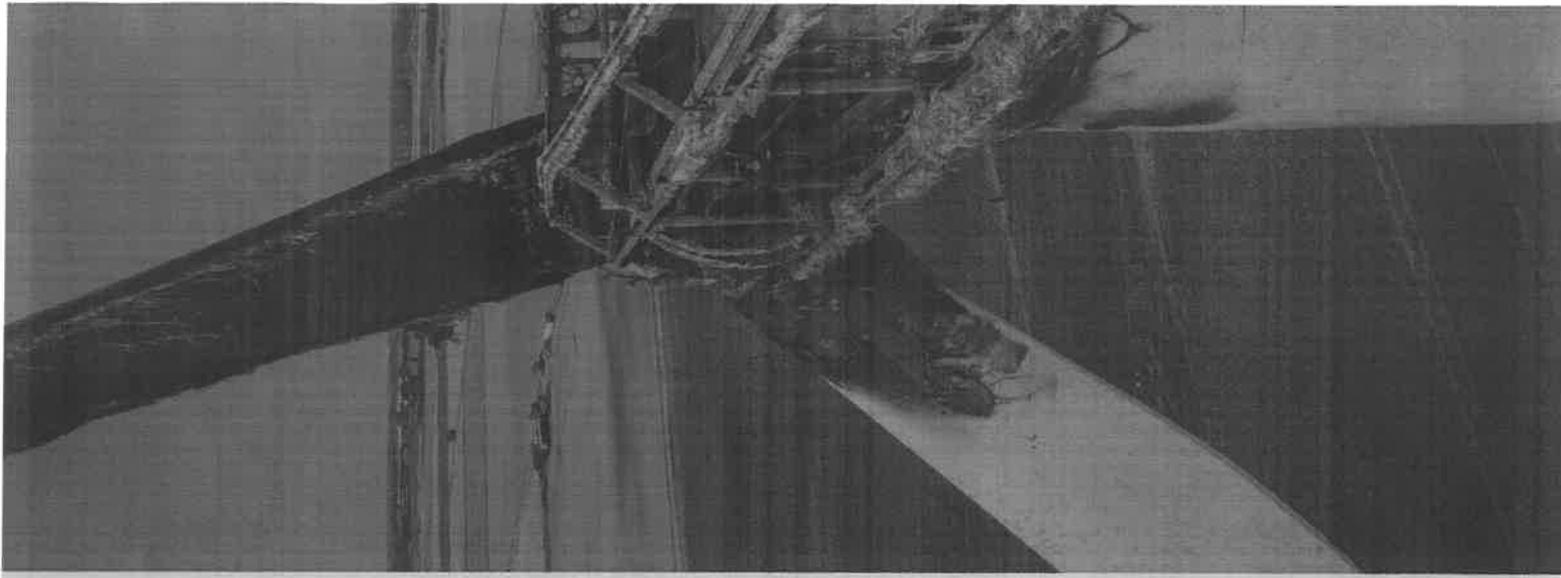


## **GUIDELINES FOR RECOMMENDING FIRE SUPPRESSION SYSTEMS**

Although each customer will be different, we believe that the following table provides practical guidelines for the recommendation of fire suppression systems.

This analysis assumes that a typical wind turbine is valued at \$1M per MW. Given that most turbine fires result in a total loss of the turbine, this is the investment that is at risk with a wind turbine fire. We have also assumed a rate of 1 fire per 2,000 turbines per year, based on data from Wind Power Engineering Magazine presented earlier in this report.

This approach leads to stronger protection for larger and more expensive wind turbines. As the size and capacity of wind turbines increases both on shore and off shore, owners and operators should re-evaluate their approach to fire protection.

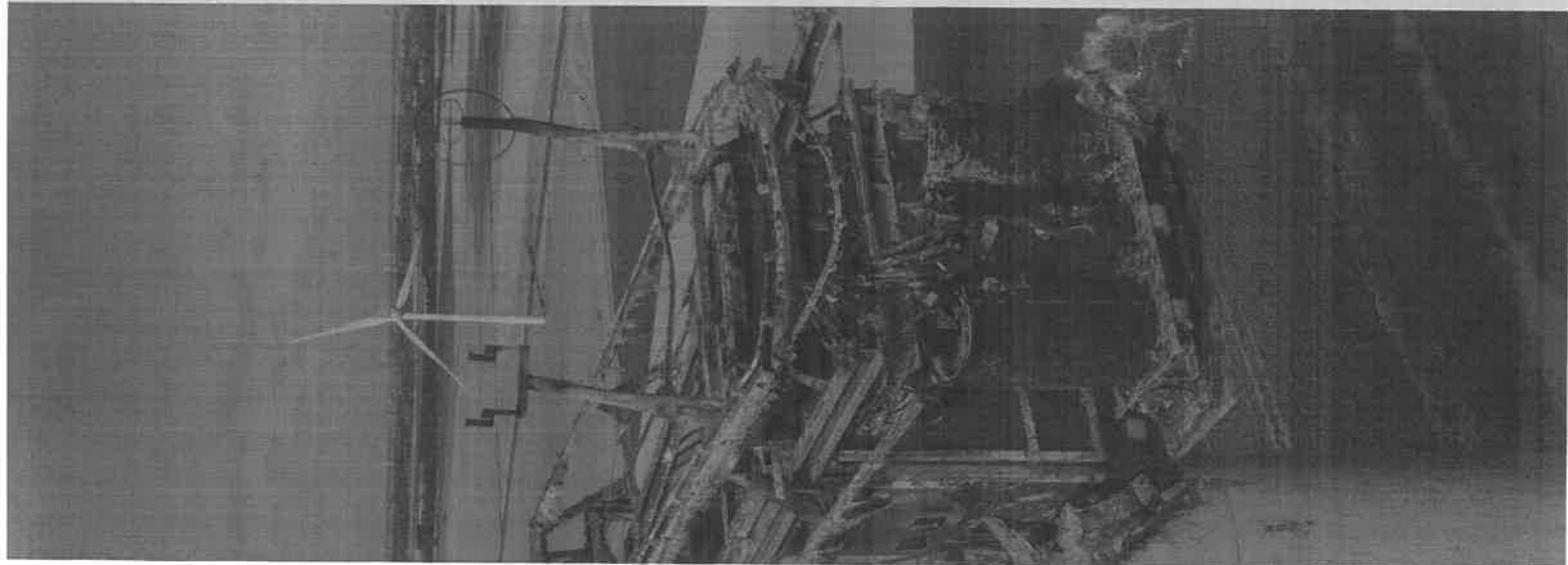


TURBINE CAPACITY	TURBINE COST	RECOMMENDED INVESTMENT*	RECOMMENDED LEVEL OF PROTECTION
1MW	\$1M	\$ 10,000.00	Capacitor & Converter Cabinets
2MW	\$2M	\$ 20,000.00	Capacitor & Converter Cabinets + Nacelle Brake Area
3MW	\$3M	\$ 30,000.00	Capacitor & Converter Cabinets + Nacelle Brake Area + Transformer
4MW	\$4M	\$ 40,000.00	Capacitor & Converter Cabinets + Nacelle Brake Area + Transformer
5MW	\$5M	\$ 50,000.00	Capacitor & Converter Cabinets + Nacelle Brake Area + Transformer
6MW	\$6M	\$ 60,000.00	Capacitor & Converter Cabinets and Nacelle Brake Area + Transformer
7MW	\$7M	\$ 70,000.00	Capacitor & Converter Cabinets + Nacelle Brake Area + Transformer
8MW	\$8M	\$ 80,000.00	Capacitor & Converter Cabinets + Nacelle Brake Area + Transformer

ON SHORE RANGE

OFF SHORE RANGE

\*Based on cost of a wind turbine, rate of fire at 1 in 2,000 per year, and typical turbine lifetime of 20 years



# HOW FIRE SUPPRESSION CAN IMPROVE YOUR INSURANCE RATES

By not having a fire suppression system, you can expect more total loss claims from fire. While your insurer may pay you a large claim after a fire, the increases to your policy can be quite large. The money has to come from somewhere. After a fire claim, you can expect to see:

1. Increased premiums
2. Increased deductibles
3. Restrictions in cover

Fire suppression systems can reduce your fire loss risk, and in turn save your insurer millions in claims. While it is difficult to reduce your premiums in this hardened insurance market, it is reasonable to communicate to your underwriter how they benefit from you having fire suppression systems. You have a strong argument for your insurers reducing an increase in premiums/deductibles or maintaining your current rate to incentivize you to install fire suppression systems.

Fire suppression systems can provide a strong return on investment even without insurance incentives, but as your insurer benefits so much from you mitigating fire loss then it is fair to prove the business case for incentives to them.



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