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Canadian Renewable Energy Association
Operations & Maintenance

Best Practices for Wind Farm Icing and Cold Climate Health & Safety

This best practice guide outlines practices and procedures to assist with the safe operation and maintenance of wind power generation facilities in cold climates.
June 2020 Edition

Best Practices for Wind Farm Icing and Cold Climate Health & Safety

Summary

Canada's wind industry faces some challenges related to operation and maintenance (O&M) in cold climate regions. Similar to other cold climate work places, operating and working in low temperatures requires properly rated equipment and specific safety procedures, including in respect of any icing that may occur.

Cold climates can increase operation and maintenance costs. For example, the presence of snow on-site requires the use of more capable vehicles or contractors to clear access roads. Also, turbines may remain shut down for longer periods, as the presence of icing hazards might limit the access of wind technicians to conduct maintenance activities.

The Canadian wind industry has given significant attention to the difficulties relating to safely accessing shutdown turbines, as this issue results in significant monetary losses. Certain icing events can induce multiple days of downtime during which the turbine cannot be safely entered and energy production is not possible. These topics warrant continued attention by the industry.

Historically original equipment manufacturers (OEMs), operators, and independent service providers have developed their own procedures and best practices for cold climate health & safety. The industry best practices collected in this document are informative, not only to further encourage a safe and healthy workplace for wind industry employees and the public but also to help address in a consistent fashion the industry's main preoccupations regarding O&M in Canadian cold climate regions.

This guide therefore presents a collection of best practices for wind farm icing and cold climate health & safety. These best practices come from a consensus of the Canadian wind industry's practices, up-to-date and reliable literature, and federal regulatory requirements.

They have also been revised by the Canadian Wind Energy Association's (CanWEA) Icing and Cold Climate Safety Subcommittee of the O&M Caucus, which is made up of wind energy experts. This edition was updated in June 2020 to include new best practices and references published since 2017.

Although these best practices do not replace regulatory requirements (which much still be followed), it is the intent of this document to provide a tool to the industry that helps assist with the management of health & safety regarding wind farm O&M in cold climate areas, provide confidence to those operating wind turbines and indirectly promote wind power progress in Canada and other cold climate regions. It is important to note that even if operation & maintenance costs are increased, wind farms in cold climate areas generally benefit from abundant winds at high air densities [1].

The first section of this document defines terms such as cold climate, low temperature, icing, maximum ice throw zones, hazards related to icing, and more.

Given the purpose of this document, the terms "hazard" and "risk" herein refer to the definitions from the Canadian Centre for Occupational Health and Safety: "A hazard is any source of potential damage, harm or adverse health effects on something or someone" and a "risk is the chance or the probability that a person will be harmed or experience adverse health effect if exposed to a hazard."[2] . Emphasis is placed on the potential nature of hazards as mitigation efforts can decrease the risk of a hazard resulting in harm.

The second section covers general physical conditions: requirements for icing to occur, typical regions for icing, the different ice types and their characteristics, requirements for low temperatures, weather conditions, typical regions for low temperatures, typical equipment temperature ratings, types of ice in low temperatures, the probability of icing versus air temperature, and more.

The third section defines documented hazards related to icing and low temperatures: ice fall, ice throw, poor visibility, frostbite, hypothermia, wind chill, etc.

The fourth section details basic guidance relating to safety, employees, employers and supervisors' responsibilities regarding health and safety, a method for risk assessment, and the best practices related to operations and maintenance in cold climate areas.

Finally, the last section presents a decision tree to help select the best practices according to the documented hazards related to wind farm O&M in cold climate areas.

Since every site has its own unique terrain, buildings, access roads, etc., other practices or a combination of practices other than those presented in this document might be more suitable for a specific condition. Any guidance contained herein should be evaluated on a case-by-case basis and may need to be revised or supplemented to given specific conditions, including to ensure compliance with regulatory requirements.

> Please note that the risk of injury is always present even when following these best practices, as they do not guarantee worker or equipment safety. Stay alert and always be aware of the environment and changing conditions when working, particularly in cold climate areas.

> One should not perform a task that seems dangerous, regardless of the best practice established in that condition. Since regulatory requirements vary between provinces and territories, and that this guide is intended for Canada's wind industry, provincial/territorial requirements have not been considered. Make sure that the best practices described in this section respect the provincial and any other regulatory requirements where the operation or maintenance work is performed. Make proper modifications if needed.

Revision History

Edition	Note
December 2017	Initial release of document
June 2020	New section: 1.1.4 Rotor Icing Updated sections: 1.5.1 Ice Throw 4.1.3 Public Safety 4.4 Turbine Approach References

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Contents

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Definitions

Icing

Icing refers to any type of accumulation of ice or snow on a structure. Icing occurs when water present in the air freezes after it comes in contact with a surface. This can either occur within clouds (in-cloud icing) or result from precipitation (precipitation icing). In-cloud icing usually forms rime, while precipitation icing forms glaze, drizzle or wet snow. All ice types are defined in section 0.

Meteorological Icing

Meteorological icing is the period during which atmospheric conditions are favorable for ice buildup on structures. This active phase of icing is also referred to as the ice accretion period.

Accumulation

Accumulation is the total precipitation. There can be accumulation of snow, rain, freezing rain, hail, etc. Not all the precipitation will stick to the structure and contribute to ice accretion.

Instrumental Icing

The total duration of the presence of ice on structures is defined as instrumental icing. Ice can still be present on the site for days after meteorological icing.

Rotor Icing

The period during which ice is present on the rotor blade of a wind turbine is defined as rotor icing. Mainly since the geometry of the blades and the relative velocity of the wind acting upon them are very different compared to a fixed structure, rotor icing is not equivalent to instrumental icing [1][3]. Typically, ice can accrete faster on the rotor and the ablation phase is shorter than for instrumental icing. Furthermore, the duration of rotor icing strongly differs for a wind turbine at stand-still compared to an operating turbine [1].

IEA Ice Class

IEA wind task 19 has established a classification for icing climate sites according to meteorological icing, instrumental icing, and production losses. This classification gives a first indication of the severity of icing and its consequences at a given site [1]. IEA Ice Classes are defined in Table 1.

Table 1: IEA Ice Class Definitions

IEA Ice Class	**Meteorological icing** (% of the year)	**Instrumental icing** (% of the year)
1	0-0.5	0-1.5
2	0.5-3	1-9
3	3-5	6-15
4	5-10	10-30
5	>10	>20

When using the IEA Ice Classification, a site can end up in different ice classes depending on the input used for the classification (meteorological icing or instrumental icing). In that case, it is recommended to use the highest class [1].

Wind turbines installed on these sites are designed to withstand icing loads per the international standard IEC61400-1:2019 [4] and DNV-GL Recommended Practice DNVGL-RP-0175 [5].

There are different ways to determine icing occurrence, from site measurements to meso-scale modelling [6]. One such method is the wind power icing atlas (WIceAtlas) created by the VTT Technical Research Centre of Finland which provides probability levels of in-cloud icing severities worldwide. The following figure (Figure 1) illustrates the distribution of icing severities across Canada according to the methodology used by VTT.

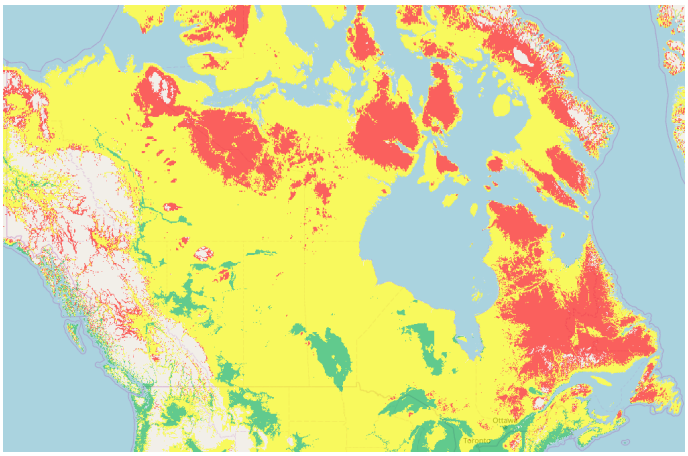


Figure 1: Canadian IEA Ice Class Distribution [7]

IEA Ice Class	1	2	3	4	5
Figure 3 Corresponding Colour					

The different ice classes on the map represent areas with varying icing severities in terms of meteorological icing, instrumental icing, and production loss. IEA ice classes are defined in Table 1. The white regions on the map lack sufficient data to estimate the ice class. A site with no icing

occurrence over the year would be of Ice Class 1, and therefore is green on the map.

This map also illustrates the variability of the icing climate over Canada, with Eastern Canada being the region with the highest occurrences of icing. Local areas can also have different ice classes depending on the terrain elevation.

Low Temperature

In the context of structural design, and according to the IEC61400-1 standard on wind turbine design load cases, a low-temperature climate site is a site where one of the following conditions is fulfilled [1] :

- An average annual air temperature of 0°C or below;
- Nine days or more (over the year) with at least one hour with an air temperature average of -20°C or below.

However, in the context of health and safety, employees can be at risk at temperatures below 0°C.

Cold Climate

Cold climate regions are affected by icing and/or low temperatures. Even if wind energy is generally higher in lower air temperatures (air is denser), cold climate sites may result in increased O&M costs and hazards related to user safety [1]. Figure 2 illustrates the definition of cold climate according to the IEA wind task 19.

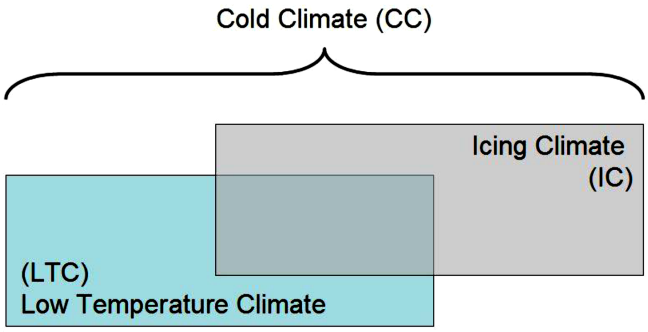


Figure 2: Definition of Cold Climate

Hazards and Risks

Given the purpose of this document, the terms “hazard” and “risk” herein refer to the definitions from the Canadian Centre for Occupational Health and Safety: “A hazard is any source of potential damage, harm or adverse health effects on something or someone” and a “risk is the chance or the probability that a person will be harmed or experience adverse health effect if exposed to a hazard.”[2].

Hazards Related to Icing

If icing occurs, it may affect wind turbine operations and maintenance in different ways. For instance, if ice accretes on rotor blades, it reduces the aerodynamic performance of the turbine and is likely to induce production losses. Also, rotor blade icing increases vibrations and fatigue loads and can reduce turbine lifespan [8]. Icing on a wind turbine may also lead to measurement and control errors as well as mechanical and/or electrical failures.

After an icing event, icing related hazards such as ice throw or ice fall are most likely to occur when temperatures rise and are close to or above 0°C. Ice tends to shed because of small vibrations or blade bending [9].

It should be noted that ice fall is not only limited to wind turbines, as accumulated ice may fall from any iced structure on a wind farm.

Ice Throw

When a turbine is in operation and if the ice detaches from the moving blades, it can be projected away from the turbine. Wind direction, wind speed, rotational speed as well as position and size of the ice fragments on the blade will influence the landing position of the projected ice pieces.

The maximum throwing distance for ice throw can be determined with the following empirical formula [10]:

$$d_t = 1.5 * (D + H)$$

d_t = Maximum throwing distance (m)
D = Rotor diameter (m)
H = Hub height (m)

The ice throw zone or the maximum throwing distance can be represented by the red circle of Figure 3.

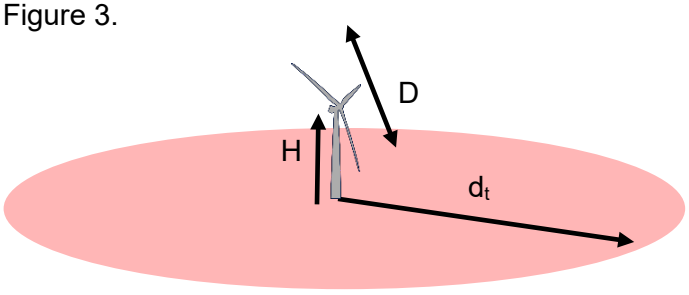


Figure 3: Maximum throwing distance area

The risk of being struck by an ice piece thrown for the blade when standing outside of the ice throw zone is

considered null. Within the ice throw zone, this risk increases as one gets closer to the turbine [11].

The formula approach is widely accepted as being conservative (i.e. Ice throw will remain within this zone). However, it does not allow the probability of an ice throw impact within the ice throw zone to be evaluated. A more detailed analysis based on ballistic computer models may allow for a resizing of the ice throw zone. This analytic approach can also provide the probability of an ice fragment hitting the ground, expressed as the number of strikes per square metre [6]. IEA Wind TCP Task 19 published detailed guidelines for analytical ice throw risk assessment in 2018 [11].

Ice Fall

Ice may fall from any structure. The trajectory of the ice fall is subject to wind speeds, wind directions and size of ice fragments. A maximum falling distance for non-operating wind turbines can be established with the following empirical formula [10]:

$$d_f = \frac{\frac{D}{2} + H}{15} * V$$

d_f = Maximum falling distance (m)
D = Rotor diameter (m)
H = Hub height (m)
V = Wind speeds at the hub's height (m/s)

A more detailed analysis and an advanced simulation may allow the maximum falling distance to be made smaller.

Meteorological mast and other structures also have their own ice fall zone. In those cases, the maximum distance for falling ice can be approximated using the following formula [9]:

$$d_f = \frac{3 * H}{2}$$

d_f = Maximum falling distance (m)
H = Structure height (m)

Ice Ablation

Ablation is a general term that refers to the reduction in volume of the ice. Ice can melt, break, shed or sublimate (evaporate) and all of these actions contribute to ablation.

Ice Shed

Ice shed is a general term that refers to either ice fall or ice throw. The following picture (Figure 4) was taken from a hub camera. It illustrates craters from ice pieces that fell or were thrown from a turbine.

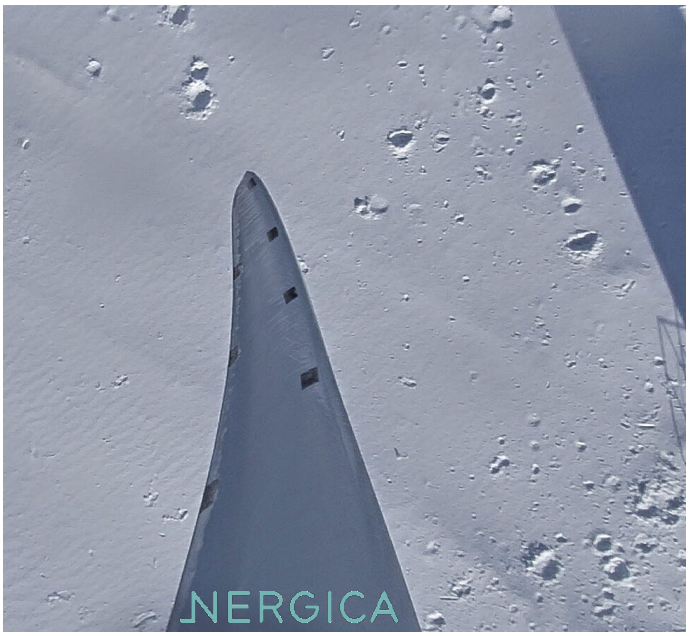


Figure 4: Ice shed craters [12]

Physical Conditions

Requirements for Icing

The formation of ice depends on various conditions, including air temperature, wind speed, shape of the object, liquid water content, and droplet size distribution [9]. However, the two principal factors to consider are :

- Air temperature ranges between 3°C and -20°C;
- The structure is within a cloud or there is precipitation.

Below -20°C, atmospheric icing is rare because clouds at this temperature consist of ice particles rather than water droplets, and therefore do not freeze on structures. Also, precipitation below -5°C is not likely to stick on structures.

Ice Types

Atmospheric icing refers to any type of accumulation of ice or snow on a surface caused by a meteorological event. This type of icing is mainly caused by precipitation, such as freezing rain and wet snow, or by passing clouds and fog. The different forms of atmospheric icing are described below.

Rime

Rime is caused by the instantaneous freezing of supercooled water droplets (liquid water at temperatures below 0°C) upon coming in contact with a structure. This type of ice most often forms in a homogeneous, cloudy environment and will accumulate on the structure's surface exposed to the wind. Figure 5 shows a typical light rime accumulation on a turbine blade. In this picture, the main icing event had passed and ice had started to shed.

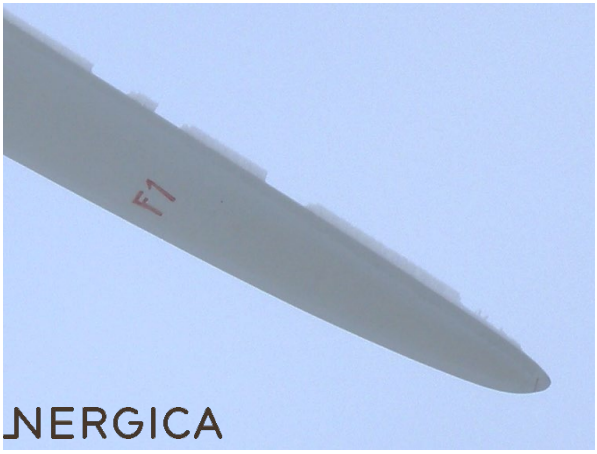


Figure 5: Example of light rime on a wind turbine blade

The density of this type of ice is proportional to the size of the supercooled water droplets. The larger they are, the denser the ice will be. Rime can be divided into soft rime and hard rime. Soft rime has a density ranging from 200 to 600 kg/m^3, has a white color, and has low to medium adhesion to structures. Conversely, hard rime has a density ranging from 600 to 900 kg/m^3, has an opaque color, and has strong adhesion to structures [9]. As crystallization occurs rapidly, a great deal of air is trapped in the ice, giving it an irregular and brittle character as shown in Figure 6.

Figure 6: Heavy rime on a wind turbine blade

This type of ice generally forms at temperatures ranging from 0°C to -20 °C.

Glaze

Glaze ice is also known as clear ice and is caused by different types of supercooled precipitation that freezes upon contact with a cold structure. However, due to the release of latent heat, it can expand on the structure before freezing. Therefore, no air is trapped in the ice. The ice will be regular, transparent in nature, and will not crumble, therefore this type of ice may be difficult to detect visually. Figure 7 shows a picture of glaze accumulation on a wind turbine rotor.

Figure 7: Typical glaze accumulation on wind turbine rotor

Glaze can sometimes be hardly visible since it is usually thin and transparent. This type of ice has a density of approximately 900 kg/m^3. It is generally produced at temperatures ranging from 0°C to -6°C, combined with freezing rain. On roads, a thin and transparent layer of glaze is often referred to as black ice.

Wet Snow

When temperatures fluctuate between 0 °C and 3°C, snow crystals with a high water content can adhere and bond to structures. When the temperature drops, accumulated wet snow freezes to form ice that has a density varying between 300 and 600 kg/m^3. Visually, it resembles rime.

Hoar frost

At very low temperatures, the likelihood of ice formation diminishes, as the water droplets no longer exist in a supercooled state. However, another phenomenon may occur, namely the solid condensation of water vapor in the air. This type of ice, known as hoar frost, is produced when relative air humidity is high (above 90%) and winds are low. Although this type of ice is responsible for corona losses on power transmission lines, its density and bond strength are low, which limits the mechanical loads imparted on the structures[9]. As a result, hoar frost is also less dangerous in terms of ice shed.

Ice Locations

On a wind farm, ice can form on buildings, power lines, roads, walkways, stairs, towers, nacelles, hubs, blades, weather masts, and any other structure.

Requirements for Low Temperature

When considering worker health and safety, a low temperature climate is an environment in which one feels uncomfortable with the cold or there is potential for injury due to the low temperatures.

According to the IEA Wind Task 19, a low-temperature climate site is a site where one of the following conditions is fulfilled [1]:

- An average annual air temperature of 0 °C or below;
- Nine days or more (over the year) with at least one hour with an air temperature average of -20°C or below.

This definition of low temperature climate site is for the design load cases of turbines and it should not be used for health and safety concerns.

Weather Conditions

Extreme cold can occur through the combination of wind and low air temperature. When evaluating the air temperature for outdoor work, wind speed has to be taken into account, as it increases the rate at which the human body loses heat. Wind chill is especially important to consider on wind farms since turbines are purposely located on sites with high winds.

Table 2 and Table 3 present apparent temperatures that take into consideration wind chill and the corresponding exposure risks [13].

Table 2: Apparent Temperatures Considering Wind Chill

Air Temperature (°C) \ Wind Speed (m/s)	0	5	10	15	20	25	30
0	0	-5	-7	-8	-9	-10	-11
-5	-5	-12	-14	-15	-16	-17	-18
-10	-10	-18	-21	-22	-23	-25	-26
-15	-15	-24	-27	-29	-30	-32	-33
-20	-20	-30	-34	-35	-37	-39	-40
-25	-25	-37	-41	-42	-44	-46	-48
-30	-30	-43	-48	-49	-51	-53	-55
-35	-35	-49	-54	-56	-58	-61	-62
-40	-40	-56	-61	-63	-65	-68	-70
-45	-45	-62	-68	-69	-72	-75	-77
-50	-50	-68	-74	-76	-80	-82	-84

Table 3: Exposure Risks of Apparent Temperature

Corresponding Colour	Exposure Risk	Approximate Delay until Exposed Skin Freezes (min)
	Low Risk	
	Moderate Risk	
	High Risk	10 – 30
	Very High Risk	5 – 10
	Severe Risk	2 – 5
	Extreme Risk	< 2

Typical Regions for Low Temperature

The following figure (Figure 8) from Environment Canada, illustrates the average ambiant temperature in December, January, and February (e.g. the winter) from 1981 to 2010.

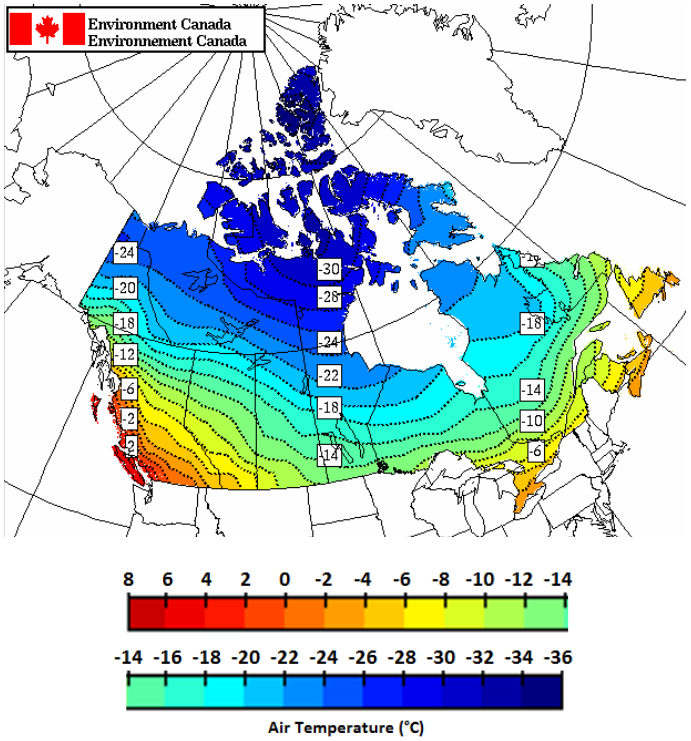


Figure 8: Temperature Climatology – Map – Average – Dec Jan Feb (Winter)[14] © Her Majesty the Queen in Right of Canada, as represented by the Minister of the Environment Canada, [2017]

Typical Equipment Temperature Ratings

Under extreme temperatures, materials react differently. In extreme cold, metals and many other materials weaken and equipment or tools can break or stop working.

Table 4 presents the temperature ratings of general equipment commonly used on a wind farm. The temperature rating will vary depending on the brand and model for all equipment listed. Therefore, always validate the temperature rating of the equipment before using it in low temperatures. The temperature rating is independent of the apparent temperature. It depends on the thermometer value, regardless of the wind chill.

Table 4: Typical Equipment Temperature Ratings

Equipment	Description	Min. Temp. Rating
Harnesses	Skylotech Harness G0051	-35°C
	DBI SALA ExoFit	-35°C
Helmets	UVEX pheos E-S-WR	-30°C
	Petzl Vertex Best Canada Vers.	-30°C
Lanyards	Petzl lanyard	-40°C
	DBI SALA Force 2	-35°C
Vertical life line	DBI SALA Lad-Saf	-35°C
Descent devices	Tractel Derope	-35°C
Cell phones	iPhone	-20°C
Sat. phones	Global Star 9600	-20°C
Multimeters	Fluke 179	-10°C
Ladder Runner	Bornack RS S05 CSA	-30°C
LMB Ladder System	Normal Climate	-20°C
	Cold Climate	-40°C
Service lifts	Dolphin V CE 240 and 350	-15°C
	EL3 CSA Service Hoist	-20°C
	Power Climber	-29°C

Icing in Low Temperature

There is an overlap between icing and low temperature when ice accretes on structures at temperatures below
-20°C. Ice type then differs from usual in-cloud icing and some physical factors are unique in these conditions.

Types of Ice in Low Temperatures

At low temperatures (below -20°C) liquid water content in the air becomes very rare and practically no in-cloud icing occurs [6]. Below -20°C, hoar frost may happen.

Figure 9 shows typical ice type as a function of air temperature and wind speed [6].

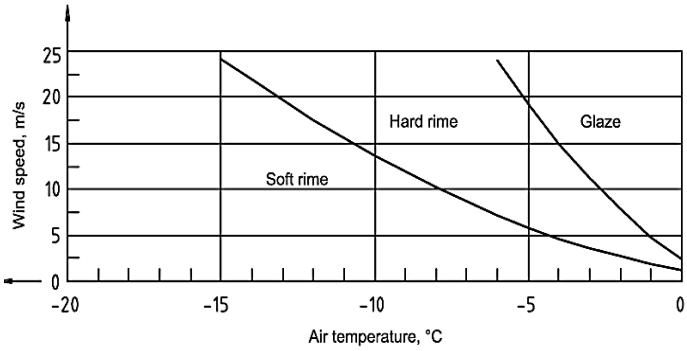


Figure 9: Type of ice as a function of wind speed and air temperature [9]. ”Copied by Nergica with the permission of the standards Council of Canada (SCC) on behalf of ISO”

The curves of Figure 9 shift to the left as object size decreases and liquid water content rises [9]. Around air temperatures of -20°C, in-cloud icing is rare and the most frequent ice type, in this case, is soft rime.

In that temperature range, icing still occurs and mainly forms hoar frost.

Physical Factors that are Unique to Overlap

Figure 10 illustrates the relationship between the probability of ice formation and air temperature [15].

Even if the probability of ice formation is much higher at a temperature range of 0 to -15°C, one factor to consider is the persistence of icing. For instance, if the temperature drops after an icing event, the ice will remain on structures for a long period of time, which can amount to weeks. After an icing event, health and safety procedures should apply until it has been confirmed that no ice is present on the site.

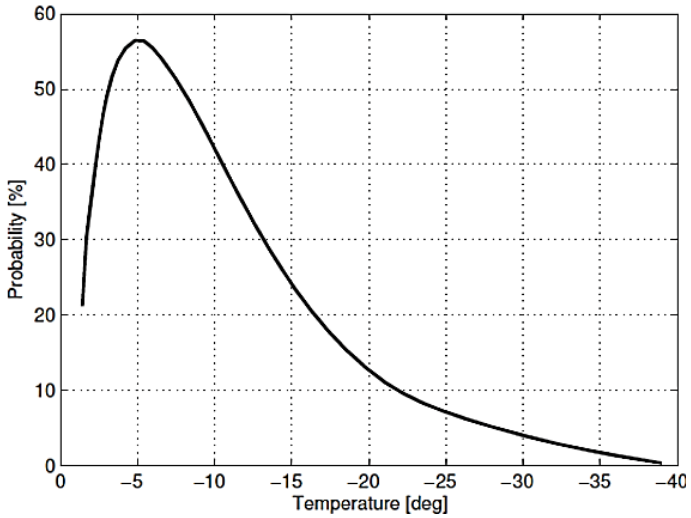


Figure 10: Probability of ice formation as a function of air temperature [15]

The probability of meteorological icing decreases with low air temperatures because liquid water droplets in the air turn to ice as they freeze. Figure 10 must be interpreted carefully as the probability of icing is not related to the probability of ice persistence or ice shedding.

Ice shed tends to occur in mild temperatures when the ice starts to melt. Therefore, temperatures close to 0°C increase the risk of ice shed. Nonetheless, if there is ice present, the same precautions must be taken regardless of the air temperature.

Ice Detection Methods

There are different ways to evaluate the presence of ice on site rather than visual inspection. Ice detection methods are good indicators of the actual presence of ice on site. However, since they all have their limitations, they should not be used to assess the absence of ice. Ice detection methods should only be used to postpone on-site work if they suggest icing.

Double anemometry

The double anemometry is an ice detection method that compares wind speeds from heated and unheated anemometers. Over an icing event, unheated anemometers will freeze and underestimate the wind speed. This ice detection method requires the use of both unheated and heated anemometers, which may not always be installed on a given site. If in-cloud icing only occurs higher than the nacelle, it may go undetected by double anemometry but still contribute to ice accretion on blades.

Ice detectors

They are a lot of different ice detectors on the market for various applications. For example, some ice detectors only detect meteorological icing while others detect instrumental icing. Also, ice detectors can give information on nacelle icing and/or blade icing depending on the type of device. Therefore, one should be mindful of the detector's application when interpreting ice detector data.

Power deviation

The power deviation method detects the presence of ice on the blades by comparing produced power and expected power. As ice reduces the aerodynamic performance of the blades, for a given wind speed, produced power will be inferior to expected power. However, this method does not work on shut down turbines or with very low wind speeds.

Snow Vehicles

Over the winter, the use of snow vehicles is essential to travel on un-cleared service roads. There are many different types of snow vehicles and each of them have their preferred use.

Snowmobiles

Snowmobiles are fast. They are commonly used to travel from building to building. Also, since they might be the fastest snow vehicle on site, they can be used to tow medical evacuation sleds (Figure 11):

Figure 11: Picture of a snowmobile towing a medical evacuation sled [12]

However, as they do not have a closed cockpit, drivers and passengers are exposed to the wind, cold and ice shed hazards.

Snowcats

A snowcat is a fully tracked vehicle designed to move on snow (Figure 12).

Figure 12: Picture of a snowcat

It has a closed cockpit and it is the size of a truck. They are commonly used to approach turbines and structures since they can easily be fitted with additional protection from ice shed. Also, the driver and passengers are not exposed to cold or the wind. One downside is that they are slow.

Trucks on tracks

Trucks on tracks or 4X4 vehicles on tracks (Figure 13) are useful when there is not a lot of snow, otherwise, they can easily become stuck in deeper snow due to their lower track surface compared to a snowcat.

Figure 13: Picture of a truck on tracks [12]

Trucks on tracks also provide the safety of a closed cockpit with respect to cold and wind protection.

Ice Protection Devices

Ice protection devices are designed to provide protection for the employees that enter the turbine. They can include both permanent structures or mobile devices.

Figure 14: Permanent ice protection device for tower entrance

Permanent installations typically take the form of a roof that covers the turbine entrance and stairs as shown in Figure 14. There are also permanents installations to protect transformers when they are located in the vicinity of the turbine as see in Figure 15.

Figure 15: Permanent ice protection device for transformers

On the other hand, mobile ice protection devices consist of a trailer with a deployable roof providing a temporary structure to safely enter the turbine. **Error! Reference source not found.** Figure 16 and

Figure 17 provide examples of custom designed devices. Use of this equipment involves specific procedures for personnel transfer from the vehicle to the wind turbine.


Figure 16: Mobile ice protection device towed by a snowcat

Figure 17: Mobile ice protection device

Hazard Definitions

After or during an icing event, a snowstorm, or during winter's coldest days, risk assessment starts when you leave home to get to work. Cold climate hazards are not limited to working hours. On the way to work roads can be icy, visibility can be reduced, or you can get frostbite while fueling your car.

Furthermore, cold climate adds various hazards to wind farm operations and maintenance crew that must be treated accordingly. It is important to be mindful of these hazards and to prevent and minimize them appropriately even though the likelihood of any significant incident resulting from these hazards is small. Those hazards are defined in the following subsections and best practices are detailed in section 0.

Icing and Snow Hazards

Potential icing hazards are mainly related, but not limited, to ice shed. Driving can be very hazardous in icing conditions; black ice can increase the risk of skidding and snowstorms can reduce visibility or form snow banks, which sometimes make the roads inaccessible.

Table 5 presents a general list of potential hazards related to icing and their definitions. The list should be considered in the context of specific site characteristics, as each site has its own structures, roads, terrain, and thus their own unique hazards.

Table 5: Icing and Snow Hazards Definitions

Ice Fall

Ice fall involves pieces that fall from structures, turbine nacelles, or stopped rotor blades. Depending on the circumstances, it may pose a risk to workers or others accessing the turbine's ice fall zone .

Ice fall can lead to serious injuries or even death. Being struck by an object with a kinetic energy over 40 Joules is considered to be potentially fatal [16]. Ice pieces of only 0.2 kg (Figure 18) can generate this amount of energy when falling from 30 to 50 meters [16].

Although falling ice has the potential to seriously injure or kill in certain circumstances, the various practices described in this document have been shown to significantly mitigate the associated risks. Proper precautions to minimize any risk associated with ice fall hazards are defined in section 0.

Figure 18: Ice piece of approximatly 0.2 kg

Ice pieces can also damage equipment located within the ice throw or ice fall zones. Section 0 illustrates how to conservatively evaluate the ice maximum falling distance. Figure 19 shows damaged stairs from an ice fall at the base of a wind turbine.

Figure 19: Damaged stairs from an ice fall

Ice Throw

Ice throw involves pieces that are thrown from an iced blade when the turbine is in operation, which depending on the circumstances may pose a health and safety risk. Ice throw pieces generally reach further distances than ice fall [17] and can weigh up to several kilograms [9] .

Proper precautions to mitigate any risk associated with ice throw hazards are defined in section 0.

Black Ice

Ice can be present on the roads, service roads, and other surfaces. When driving, black ice increases the risk of skidding and can lead to serious accidents due to the unexpected loss of traction. The same risk is present

while walking, accessing the turbine, or working on the nacelle. An unexpected fall can result in severe injuries.
Obstruction from Snow Banks/ Snow Drifts Access roads in winter are often inaccessible due to snow accumulation from storms or high winds. Snow drifts can form on roads, preventing personnel from accessing turbines or buildings. Service vehicles can get stuck in snow banks or snow drifts, exposing drivers and passengers to multiple hazards, including cold weather injuries and potential ice shed.
Snow-covered Roads The presence of snow on the roads reduces traction between the vehicle tires and the road and therefore increases the risk of skidding. Generally, there is a combination of snow-covered roads and poor visibility, as both are characteristic of snowstorms.
Snowstorms Snowstorms can often develop very quickly and are not necessarily the result of precipitation. High winds can move the snow already present on the ground, thereby making visibility extremely poor and covering roads with significant amounts of snow. Maintenance workers can become stuck in the turbine or on-site. The wind chill factor can be important during windy snowstorms.
Whiteout Within clouds or during high winds, visibility can be significantly reduced, these conditions are referred to as a whiteout. Poor visibility can make it impossible to evaluate if there is ice present on structures. Also, it is easy to get lost, particularly while coming back to the vehicle from the turbine or while driving on access roads. Moreover, poor visibility increases driving-related hazards since reaction times are reduced.

Low-Temperature Hazards

Exposure to low temperatures is hazardous. Exposed skin may freeze, causing frostnip or frostbite. Also, being cold over a prolonged period of time can lead to a drop in body temperature, a condition that can become life threatening. Low temperatures not only affect the human body but may also thicken grease and oil, weaken plastic stress resistance, weaken electric wires, reduces battery duration, etc. Table 6 defines documented hazards related to low temperatures.

Table 6: Low-Temperature Hazard Definitions

Frostnip Frost nip is a mild form of frostbite. It generally occurs on the nose, toes, fingers, and ear lobes that are exposed to low temperatures. The skin of the affected area freezes and turns white. It may feel numb. The skin feels hard to the touch, but deeper tissues still feel soft [18]. Frost nip is reversible and only causes mild discomfort. However, if no action is taken frost nip will lead to frostbite, a more severe cold injury.
Frostbite Frostbite is caused by exposure to very low temperatures or by contact with extremely cold objects (especially metal tools). Precise hand movements and holding cold tools will increase frostbite risk. Frostbite is defined by tissue temperature that falls below the freezing point. There are mild and severe cases of frostbite. Slight pain and skin inflammation are symptoms of mild frostbite while burning or prickling sensations are symptoms of severe cases. Severe frostbite sometimes shows tissue damage, but may not be painful [18].
Hypothermia Hypothermia is a drop in body temperature. It occurs at low temperatures when the body is unable to compensate for the heat loss (improper clothing or prolonged exposition to low temperatures). The first symptoms are a sensation of cold followed by pain in exposed parts of the body, shivering, and difficulty performing complex tasks with the hands. If body temperature does not increase, the next symptom is numbness, which causes the pain and sensation of cold to go away. Muscular incoordination can also become apparent. The last symptoms before death are drowsiness, interruption of shivering, diminished consciousness, dilated pupils, and coma [18].
Human Behaviour Cold temperatures affect the human body physiologically and psychologically in ways that can be hazardous for wind farm O&M. Physiologically-speaking, cold temperature is known to increase reaction time, muscular dexterity and touch sensitivity. This can lead to dropped tools or increased stumble risk. Also, in extreme cold, the body is fully engaged in maintaining the core temperature and therefore there is no significant energy to attend to usual physical and mental work [19]. Usual tasks can take longer to complete and proper decisions (regarding work or safety assessment) are harder to make. Moreover, as cold temperatures can cause general discomfort, one can tend to get the job done faster. This can result in neglected safety precautions, and hence increase the risk of injuries, endanger wind turbine production, and increase the risk of mechanical or electrical failure.
Wind Chill Wind chill is a reduction of the apparent temperature as a function of wind speed. As wind speed increases, the apparent temperature drops. Wind chill has to be considered in order to select proper clothing and exposition duration, as it will influence all hazards related to cold injuries. Table 2 shows apparent

temperatures for different wind speeds and air temperatures.
Cold Equipment/Tools In low temperatures, all unheated equipment can become extremely cold. Doors, hatches, locks, ladders, tools, and other equipment can freeze, and therefore require more precaution, and time before use. Frozen tools increase the risk of frostbite, as heat will flow from the hand to the frozen tool rapidly. Due to thermal conduction properties, the risk of frostbite is higher if the tool is made of metal as opposed to plastic.
Mechanical Issues Cold temperature makes some materials, such as plastics and metals, more brittle. Therefore, the use of equipment outside the temperature rating range may result in mechanical failure. Loads that would have induced elastic deformation or no deformation at all in warm temperatures can cause a material to fracture in cold weather. Thus the importance of respecting the temperature rating of all equipment, especially personal protective equipment (PPE).
Electrical Issues Cold electrical transmission equipment can suffer thermal shock if energized below temperature ratings. Frost can build up in electrical cabinets and bus bars after a prolonged stop from the cold and air moisture. High voltage circuits should not be energized before removing frost. Low temperatures have an effect on vehicle start up. In very low temperatures, cars or other vehicles may not start up due to the battery's reduced capacity and the increase in draw from starter motor and accessories. Cell phones and battery powered tools or communication devices do not last as long in the cold.
Oil/Grease Behaviour Oil and grease thicken in cold temperatures. This can have an impact on equipment such as generators, gearboxes, motors, gears, and so on. The use of oil or grease that is not rated for cold temperatures can lead to mechanical failures and endanger the integrity of turbine components.

Best Practices

This section presents best industry practices for icing and low temperature O&M.

Best practices for cold climates detailed in this section were established based on practices currently used in the wind industry, up-to-date and reliable literature, and federal regulatory requirements. There are fourteen jurisdictions in Canada regarding occupational health and safety (OH&S) legislation: one federal, ten provincial, and three territorial [20]. Federal requirements basically cover employees of the federal government and companies that operate across provincial borders. Since regulatory requirements vary between provinces or territories and this guide is intended for Canada's wind industry, provincial/territorial requirements have not been considered. Make sure that the best practices described in this section respect the provincial regulatory requirements in which the operation or maintenance work is performed. Make proper modifications if needed. Appendix A contains the contact information for each province and territory to obtain the respective regulatory requirements.

Since every site has its own terrain topography, buildings, access roads, etc., practices or a combination of practices other than those presented here might be more suitable for a specific condition. Staff training is, therefore, an important process to ensure proper safety measures are applied in all areas of a wind farm.

Please note that a risk of injury always remains even when following these best practices, as they do not guarantee user or equipment safety. Stay alert and always be aware of the environment and changing conditions when working, particularly in cold climate areas. Hazard identification, assessment, and control are ongoing processes. One should not perform a task that seems dangerous, regardless of the best practices established in that condition.

General

This section provides basic guidance on safety, general risk assessment and the best practices regarding general work and hazards for wind farm O&M in cold climates.

Basic Safety Guidance

Although occupational health and safety requirements vary between provinces and territories, there are basic and common responsibilities provided by the Canadian Centre for Occupational Health and Safety (CCOHS):

Employee's Rights and Responsibilities [19]

- Work in compliance with OH&S acts and regulations;
- Use PPE and clothing as directed by the employer;
- Report workplace hazards and dangers to the supervisor or employer;
- Work in a safe manner, as required by the employer, and use the prescribed safety equipment;
- Tell the supervisor or employer about any missing or defective equipment or protective device that may be dangerous;
- Right to refuse unsafe work;
- Right to participate in workplace health and safety activities organized by the Health and Safety Committee (HSC) or to become a worker health and safety representative;
- Right to know or to be informed of potential dangers in the workplace.

Manager or Supervisor's Responsibilities [19]

- Make sure workers work in compliance with OH&S acts and regulations;
- Make sure that workers use prescribed protective equipment devices;
- Inform workers of potential and actual hazards;
- Provide workers with written instructions as to the measures and procedures to be taken for their protection;
- Take every reasonable precaution in the circumstances for the workers' protection.

Employer's Responsibilities [19]

- Establish and maintain a health and safety committee or ask workers to select at least one health and safety representative;
- Take every reasonable precaution to ensure the workplace is safe;
- Train employees on all potential hazards and on how to safely use, handle, store, and dispose of hazardous substances, as well as how to handle emergencies;
- Supply PPE and ensure workers know how to use and handle the equipment safely and properly;

- Immediately report all critical injuries to the government department responsible for OH&S;
- Appoint a competent supervisor who sets the standards for performance and who ensures safe working conditions are always observed.

By law, the employer must provide the employee with a safe and healthy workplace. It is also the supervisor's responsibility to ensure that employees understand how to safely conduct their work. It is the employee's responsibility to work safely [19].

According to the Canadian Centre for Occupational Health and Safety (CCOHS), the following are basic, on-the-job safety elements related to working in cold climates [19] :

1. The right way is the safe way of doing the job; Follow instructions and ask questions;
2. Know potential hazards;
3. Know safety rules for specific jobs;
4. Follow emergency procedures;
5. Report all injuries;
6. Know emergency equipment;
7. Use personal protective equipment;
8. Learn special safety procedures;
9. Understand seasonal safety;
10. Lock out and tag all energy sources of all machinery and equipment under repair;
11. Wear proper clothing;
12. Off-the-job safety is equally important.

Risk Assessment

Risk assessment describes the overall process of identifying hazards, analyzing and evaluating the risk associated with that hazard, and finally of determining appropriate solutions to eliminate or control the risk [21].

Risk assessment should be done by supervisors, workers and other competent persons who have good working knowledge of the situation, and most importantly, who are capable of making an objective judgment. There can be many reasons to perform risk assessments on wind farms in cold climate areas. Those reasons include, but are not limited to:

- There are low temperatures, icing, or both;
- Meteorological conditions may have varied since the last risk assessment was performed;
- There is a new procedure regarding winter turbine access, mast climbing, or any other activity;
- Your location increases the probability of occurrence of some hazards;
- There is a new member in the crew;
- There is new equipment;
- There is new information concerning hazards;
- The activity has never been done before.

Also, assessment of risk due to cold climate should be integrated into the standard job safety assessment known as JSA.

Hazard Identification

Information on the risk and hazard is essential in order to properly conduct a risk assessment. For wind farm O&M, and especially in cold climate areas, specific data is needed upfront to ensure proper risk assessment and mitigation. This data is essential to identify hazards and to determine an appropriate plan for the day:

- Presence of ice from an ice detection method
- Weather conditions and forecast
  - Wind speed
  - Temperature
  - Past precipitation
- Road conditions

These are essential to identify hazards and to determine an appropriate plan for the day. Once on-site, a visual inspection of the turbines and structures (before entering the ice throw zone) is also essential to assess icing hazards.

Risk Evaluation

Risk assessment is twofold. First, the probability of occurrence is considered, and then the severity of consequences (should they occur) are assessed. Table 7 and Table 8 define risk probability and severity related to wind farm O&M in cold climate areas.

Table 7: Probability ratings [21]

Probability	Definitions
Low	May occur once during a working lifetime.
Medium	May be experienced once every five years by an individual.
High	Likely to be experienced once or twice a year by an individual.

The probability of occurrence is hard to evaluate and general definitions might not always be accurate. Even though being struck by ice fragments is very rarely experienced, the probability rating is treated as medium under an iced structure.

Table 8: Severity ratings [21]

Severity	Definitions
Low	Injury that requires first aid only. Involves short-term pain, dizziness, irritation, and frostnip.
Medium	Injury requiring days off work. E.g. frostbite, mild hypothermia, minor fracture, etc.
High	Major fracture, severe hypothermia, serious head injury, significant loss of blood, fatal disease, etc.

The severity rating related to a falling ice piece is high as if it occurs, it can lead to serious injuries or even death.

Table 9 and Table 10 help evaluate the risk rating to determine which of the risks to eliminate or control first according to the CCOHS [21].

Table 9: Risk Matrix [21]

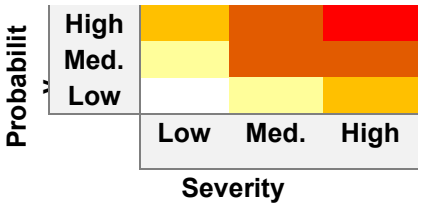


Table 10: Risk Rating [21]

Description	Colour Code
Immediately Dangerous	
High Risk	
Medium Risk	
Low Risk	
Very Low Risk	

Determine appropriate solutions to eliminate the hazard or control the risk.

Once the risk has been rated, it has to be eliminated or controlled. Table 11 describes proper general recommendations for each risk rating.

Table 11: Risk rating and appropriate recommendations [21]

Risk Rating	Recommendation
Immediately Dangerous	Stop the process and implement controls.
High Risk	Investigate the process and implement controls immediately.
Medium Risk	Keep the process going; however, a control plan must be developed and should be implemented as soon as possible.
Low Risk	Keep the process going and monitor regularly. A control plan should be considered.
Very Low Risk	Keep monitoring the process.

Regardless of the risk rating, if at any time one feel that proceeding with work is unsafe, stop work, get to a safe position, notify the person in authority, and document the hazard.

The three steps of risk assessment are an ongoing process:

1. Hazard Identification;
2. Risk Evaluation;
3. Determine appropriate solutions to eliminate the hazard or control the risk.

Risk assessment is also covered by the international standard ISO 12100:2010 [22].

Public Safety

This guide presents the best practices for wind farm icing and cold climate health & safety. It is not an exhausting collection of all the information, laws and practices available to ensure a completely safe environment for the public.

However, this section provides some practices concerning public safety related hazards.

Table 12: Best practices regarding public safety in the operation of a wind farm in cold climate

Restraint Access

- Public access to wind farms should be restricted (ideally using fences or private property signs).

Public Danger Warning Signs

- Danger signs must be visible and placed strategically. Keep in mind recreational activity trails (snowmobile, hiking, skiing, etc.). Combined with an ice detection method, these signs can be equipped with lights indicating an ongoing icing event.

Inform the public

- Inform the public; consider radio announcements, newspaper ads, snowmobile clubs, websites, and public boards.

Shutdown during icing events

- To prevent and/or reduce the risk of ice throw some turbines may be required to be shutdown during icing events. This is typically identified during the development phase of the wind farm.

Best Practices – General

Always plan your work and be aware of weather forecast and conditions. Best practices regarding general work and hazards related to wind farm O&M in cold climate areas are detailed in Table 13.

Table 13: Best General Practices in Wind Farm O&M in Cold Climate Areas

Plan your Work

- Check weather forecast
- Evaluate the presence of ice on site with an ice detection method
- Be informed of past conditions from previous work teams (Information on the presence of ice can be written in a logbook, calendar or equivalent)

Cold Temperature

- Check forecasted temperature & wind speed
- Evaluate actual and future apparent temperature
- Choose proper clothing
- Choose proper work schedule

Refer to:

- Proper Clothing
- Warm Up/Work Schedule

Proper Clothing

- Stay dry, avoid sweating
- Dress according to apparent temperature
- Dress according to the type of activity
- Loose multi-layered clothing provides the best insulation
- Waterproof and windproof outside layer
- Warm hat with ear protection
- Mittens instead of gloves when possible
- Woolen socks (carry extra pair)
- Insulated safety boots (carry extra safety shoes for indoor work)
- Face mask for cold winds (no scarf)

Snowstorm

Check forecasts before going on-site

What is the intensity of the snow storm coming?

- Severe (main roads might be hazardous) → Close office
- Low to Moderate

Is the snowstorm likely to occur while the workers are present on-site?

- Yes → Do not go on-site or evacuate wind park before the snow storm arrives
- No →
  - Proceed with work as usual
  - Stay informed of forecasts because conditions can change quickly
  - Be prepared to evacuate wind park at anytime

Lack of Visibility

Does this work involve entering in a structure's ice throw or ice fall zone?

- Yes → Postpone work until the structure is visible and an assessment of ice presence is possible.
- No →
  - Stay on known terrain
  - Proceed with work as usual

Falling Ice Hazard

- Do not approach the turbine
- Stay outside the turbine's ice throw zone
- Inform direct supervisor or site manager
- Postpone work until hazard is gone

Refer to:

- Evaluate the presence of ice
- Turbine is iced

Warm Up/Work Schedule

What is the physical work level involved?

- Heavy to moderate
- Low → Consider one step below

Work/Warm-up Schedule for outside workers based on a Four-Hour Shift

A break is 15 minutes in a warm location

Air Temperature °C	Wind Speed: No Wind		2 m/s		4,5 m/s		6,5 m/s		9 m/s	
	Max work period	No. of break	Max work period	No. of break	Max work period	No. of break	Max work period	No. of break	Max work period	No. of break
-21° to -22°	120 min	1	120 min	1	120 min	1	120 min	1	75 min	2
-23° to -25°	120 min	1	120 min	1	120 min	1	75 min	2	55 min	3
-26° to -28°	120 min	1	120 min	1	75 min	2	55 min	3	40 min	4
-29° to -31°	120 min	1	75 min	2	55 min	3	40 min	4	30 min	5
-32° to -34°	75 min	2	55 min	3	40 min	4	30 min	5	Non-emergency work should cease	
-35° to -37°	55 min	3	40 min	4	30 min	5	Non-emergency work should cease			
-38° to -39°	40 min	4	30 min	5	Non-emergency work should cease					
-40° to -42°	30 min	5	Non-emergency work should cease							
-43° & below	Non-emergency work should cease									

Frostnip

- Move to a warm location
- Do not rub the affected area

Emergency Kit

Content	Location			
	Snowmobile	Vehicle	Building	Turbine
Warming packs	x	x	x	x
Emergency blanket	x	x	x	x
Extra bedding	x	x	x	x
Water (replace once a year)	x	x	x	x
Food (Replace once a year)	x	x	x	x
Fire starter	x	x		
First aid kit	x	x	x	x
Flashlight and extra batteries (replace batteries once a year)	x	x	x	x
Pocket knife	x	x	x	x
Whistle	x	x	x	x
Sand, salt, or cat litter		x	x	x
Shovel	x	x	x	x
Fire extinguisher	x	x	x	x
Tow ropes	x	x		
Jumper cables		x		
Windshield washer fluid		x		
Shelter	x	x		
Extra fuel	x			
Spark plugs	x			
Spare belt	x			
Spill kit	x	x		
Work at height rescue kit				x

Personal Protective Equipment

- Hard hat
- High visibility vest
- Insulated safety boots
- Gloves
- Winter safety goggles
- Arc flash equipment
- Proper clothing according to the temperature (toque, number of layers, mittens)

Frostbite [18]

- DO NOT attempt to rewarm the affected area on-site (if the tissues refreeze it may cause even more damage)
- DO NOT rub area or apply dry heat
- DO NOT allow the victim to smoke or drink alcohol
- Check for signs of hypothermia and seek medical attention
- Treat the person gently and monitor breathing
- If possible, move the victim to a warm area
- Remove wet clothing and gently loosen or remove constricting clothing or jewelry that may restrict circulation
- Warm the person by wrapping them in blankets or by putting on dry clothing
- Cover the head and neck
- Warm the person slowly and avoid direct contact with heat
- Loosely cover the affected area with a sterile dressing
- Place sterile gauze between the fingers and toes to absorb moisture and to prevent them from sticking together
- If the person is alert, give them warm liquids to drink

Hypothermia [18]

- Seek medical help immediately
- Hypothermia is a medical emergency. Quickly transport the victim to an emergency medical facility.
- DO NOT warm the arms or legs directly
- DO NOT warm the person too quickly (e.g. do not use a heat lamp or soak in a hot bath)
- Ensure that wet clothing is removed
- Place the victim between blankets so the temperature can rise gradually. Be sure to cover the victim's head.
- Hot water bottles, chemical hot packs, or electric blankets may be used with caution. Wrap in a towel before applying and warm the center of the body.
- Give warm, sweet drinks unless the victim is quickly losing consciousness, is unconscious, or convulsing (avoid caffeine and alcoholic drinks)
- Perform CPR (cardiopulmonary resuscitation) if the victim stops breathing. Continue to provide CPR until medical aid is available. The body slows when it is very cold, and in some cases, hypothermia victims that have appeared dead have been successfully reanimated.

Balance of Plant (BOP)

Table 14 presents the best practices regarding the balance of plant for wind farm O&M in cold climate areas. This section covers entering buildings, transitioning from cold to warm areas, general outside work, snow removal, and general public danger warning signs.

Table 14: Best Practices related to the BOP for Wind Farm O&M in Cold Climate Areas

Transitioning from Cold to Warm Areas (vice versa)

- Avoid sweating
- Remove or add layers if necessary
- Do not wait to be cold to add layers as warming can take time
- Snow can dazzle after being inside for a certain amount of time. Consider using sunglasses or tinted snow goggles.
- Change safety shoes when working in a warm environment (do not get your feet wet).

Power Lines Protection

- Iced power lines may indicate the presence of ice on turbines.
- Remote sensing equipment will typically flag an issue.

Melting Ice and Snow on Buildings

- Get a visual of the roof before approaching buildings
- If ice or snow appears to be unstable, establish a security perimeter to ban access
- Minimize the amount of time spent alongside the walls, especially when temperature rises above -5°C
- Do not try to remove the snow while on the ground, as it can fall suddenly
- Closing doors or making small vibrations can be enough to trigger the snow/ice fall

General Outside Work

- Be careful to avoid slipping, tripping, and falling ice and snow from roofs and turbines
- Perform warm ups (strain-related injuries are more frequent in cold temperatures)
- Wear proper clothing for the temperature and the level of activity
- Try to avoid sweating by removing layers
- Stay alert to cold-related injury symptoms (frostbite and hypothermia)
- Seek shelter and get warm upon appearance of symptoms or whenever you feel uncomfortable with the temperature

Snow Removal

- Inform contractors of cold climate-related hazards. Prevent them from entering if conditions are deemed unsafe.
- Ideally, clear service roads after each snowstorm to prevent snow/ice accumulation if the wind farm is not equipped with snow vehicles
- Put salt or sand on all cleared service roads when needed (especially at intersections and steep slopes)

Electrical Hazards

- If the turbine has not been energized for some time:
- Inspect bus bars and high voltage components for frost
- Heat up electrical cabinets before energizing the high voltage circuits of the turbines: refer to turbine manufacturer procedures
- Wear arc flash-resistant clothes, properly rated gloves, and all other PPE required for electrical work

Warning Signs

- Danger signs should indicate the presence of ice shed hazards at the entrance of the wind farm and at the edge of all ice throw zones alongside service roads.
- Danger signs must be visible and placed strategically. Keep in mind recreational activity trails (snowmobile, hiking, skiing, etc.).

Turbine Close to O&M Building or Substation

- Follow the same procedure for entering a turbine

Refer to: Evaluate the presence of ice

Transportation

Table 15 presents the best practices related to transportation for wind farm O&M in cold climate areas. This section covers vehicle inspection, vehicle breakdowns, parking, winter tires, encounters with fallen power lines, broken trees, service roads, and ice fall protection trailers.

Table 15: Best practices related to transportation for wind farm O&M in cold climate areas

Vehicle Inspection

While warming the vehicle, inspect visually to ensure that:

- All lights work
- There is enough gas and washer fluid and that it is not frozen
- Tires are properly inflated

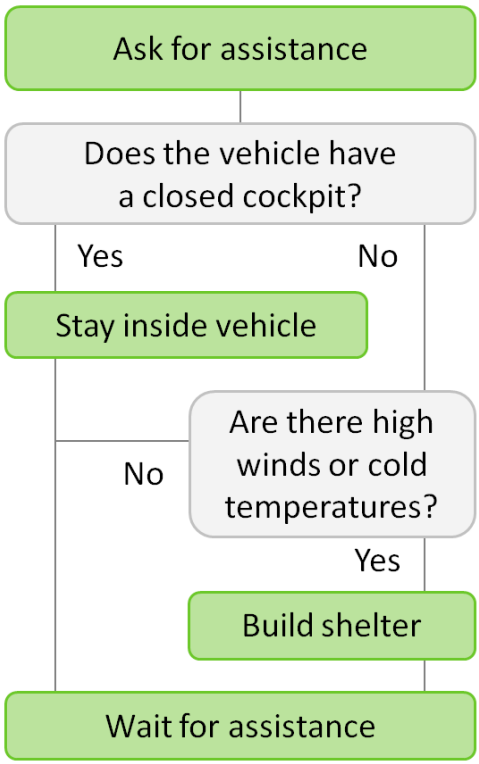
Remove:

- Snow on all surfaces
- Ice on all windows

Parking

- Park the vehicle outside the turbine's ice throw zone.
- Ensure there is a safe way to access the vehicle (i.e. no need to enter a ice throw zone)
- Leave the keys close to the vehicle and ensure coworkers know where they are
- Park the vehicle so it faces the exit

Snow Vehicle Breakdowns



Stuck Vehicles

- Pre-establish a detailed procedure to free all types of vehicles from the snow
- Ask for assistance
- Do not spend too much energy shuffling or pushing. Wait for assistance.
- If temperatures are low or there are high wind speeds, build a shelter if assistance is uncertain

Refer to: Snow Vehicle Breakdowns

Winter Tires

- During the winter or during snowstorms, all vehicles circulating on main roads or access roads must be equipped with winter tires.
- Winter tires are not designed for un-cleared service roads. In that case, use snow vehicles.

Broken Trees and Overhanging Branches

- Remove them or make them visible

Fallen Power Lines

If you see a damaged or fallen power line:

- Move to a safe location and stay away from power lines and anything they touch
- Do not try to touch or move the power line with any kind of object
- Report downed power lines to the authorities

If your vehicle comes in contact with a fallen power line:

- Do not exit the vehicle
- If the vehicle can be safely backed away from the power lines, do so
- Report downed power lines to the authorities so the lines can be de-energized

As a last resort, if it is necessary to leave the vehicle:

- Do not step out normally
- Keep your feet together
- Hold your arms tightly at your sides
- Jump clear without touching the ground and the vehicle at the same time
- With your feet together, shuffle away from the downed lines and the vehicle
- Report downed power lines to the authority

Service Roads

- Do not enter any ice throw zones of iced turbines
- If necessary, remotely shut down all the turbines with ice throw zones located near the route to the destination
- Take proper measures to prevent use of wind farm service roads for recreational activities
- Refer to: Public Danger Warning Signs
- Respect land owners
- Clear service roads before entering with trucks
- Refer to: Snow Removal
- If service roads have not been cleared, use snow vehicles

Medical Evacuation Sled

- Located at main building or strategical location in the wind farm
- Ensure it is accessible and free of snow at all times

Turbine Approach

Table 16 presents the best practices regarding turbine approach in cold climate areas: how to evaluate the presence of ice, how to assess its stability, when is it safe to enter a turbine, how to position and approach the turbine, and how to deploy ice protection devices.

Table 16: Best practices related to turbine approach for wind farm O&M in cold climate areas

Evaluate the Presence of Ice

- Validate the presence of ice with an ice detection method (double anemometry, ice detectors, or power deviation)
- Evaluate previous meteorological conditions (air temperature, precipitation, cloud height)
- Determine turbine operating state
- Obtain previous work team information (logbook or calendar)

- Do any ice detection methods suggest the presence of ice?
- Is the operating state related to icing?
- Has snow, freezing rain, or fog occurred in the last 24 hrs?
- Has the temperature been below 3°C during precipitation?
- Has the previous work team seen iced turbines?

Yes to any

No to all

- Stop vehicle outside of the ice throw zone
- Observe turbine with binoculars

- Is ice visible on the blades or on the nacelle?
- Are there ice pieces or ice shed impacts in the vicinity of the turbine?
- Does the turbine make unusual continuous noise?

Yes to any

No to all

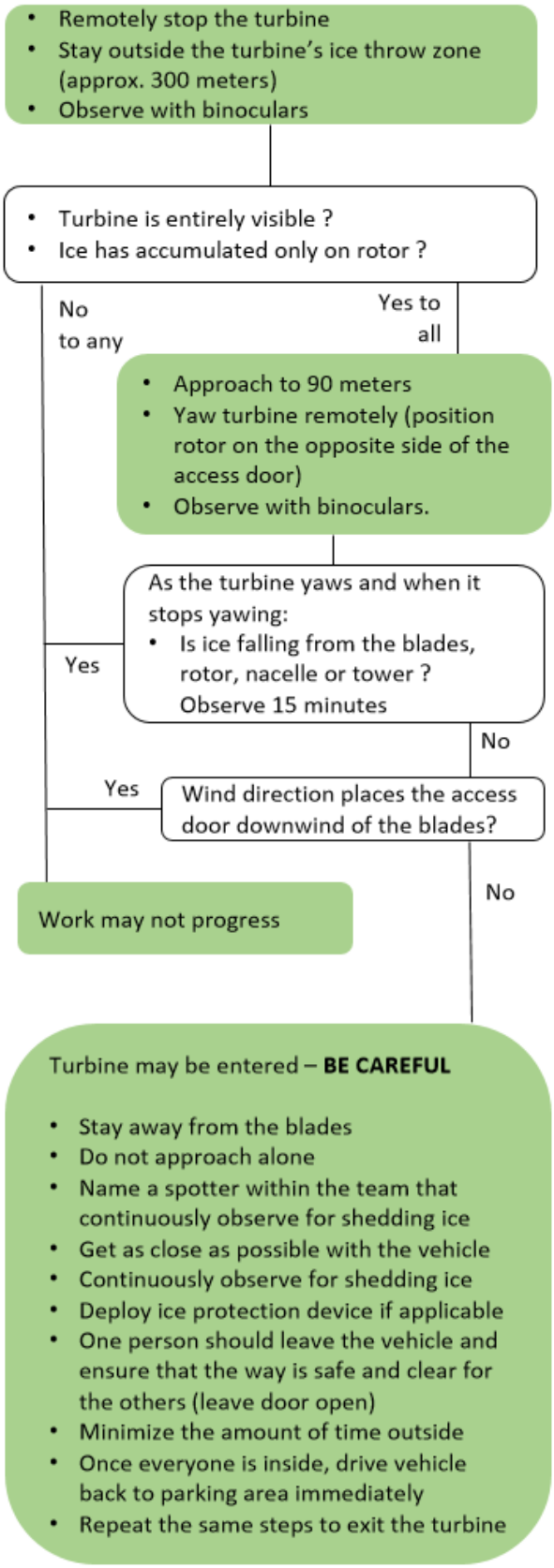
Turbine is probably iced

Refer to:

- Turbine is iced

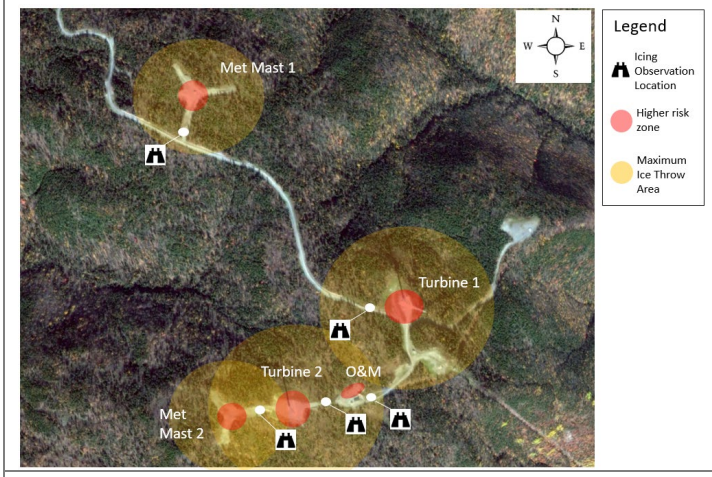
Turbine is probably free of ice. Proceed to work with caution.

Iced Turbine



Site Map for Icing Risk Assessment

A site map showing the best locations for ice fall and ice throw risk assessment can be made available to site workers to clarify the locations from which turbines can be observed at a safe distance. These locations can also be identified on the ground by a sign or post.



Vehicle Considerations

Driving snowcats can be hazardous

- Pre-establish procedures to enter and park snowcats.
- Pre-establish procedures to load and unload material from snowcats.

Refer to: Parking

Ice Protection Device Deployment

- Transformers at the bottom of the turbine and other permanent equipment should be protected with a roof or grating
- Ice protection devices should only be used when ice appears stable

Refer to: Iced turbine

Down Tower

Table 17 presents the best practices related to O&M activities inside the base of a tower in cold climate areas.

Table 17: Best practices related to down tower work for wind farm O&M in cold climate areas

Moisture & Frost

- Moisture and frost can cause short circuits
- Be aware of increased hazard of arc flashes and sparks
- Wear arc flash clothing and PPE
- If equipment is normally warmed before use, allow more time to warm than usual
- Refer to:

- Electrical Hazards

Equipment Function

- Respect the temperature rating range of all equipment
- Be aware of reduced battery life (powered tools and cell phones)
- Be aware of weakened materials, especially those in plastic
- Ladders can be cold. Wear insulated gloves to prevent frostbite. Do not use hot pads to climb as they reduce dexterity.

Frozen Access Door

Turbine is entirely visible?
Turbine is entirely free of ice?

Yes to all

No to any

Work may not progress

- Do not approach the turbine
- Stay out of the ice throw zone
- Inform supervisor
- Added time to open a door that is frozen shut will increase risk

- Stay away from the blades
- Stay alert. Ice may be present on the nacelle
- Do not approach alone
- Name a spotter within the team that continuously observes for shedding ice
- Get as close as possible with the vehicle
- Continuously observe for ice shed
- Windshield washer fluid can help to de-ice frozen areas

Refer to :

- Ice protection device deployment

Up Tower and Nacelle

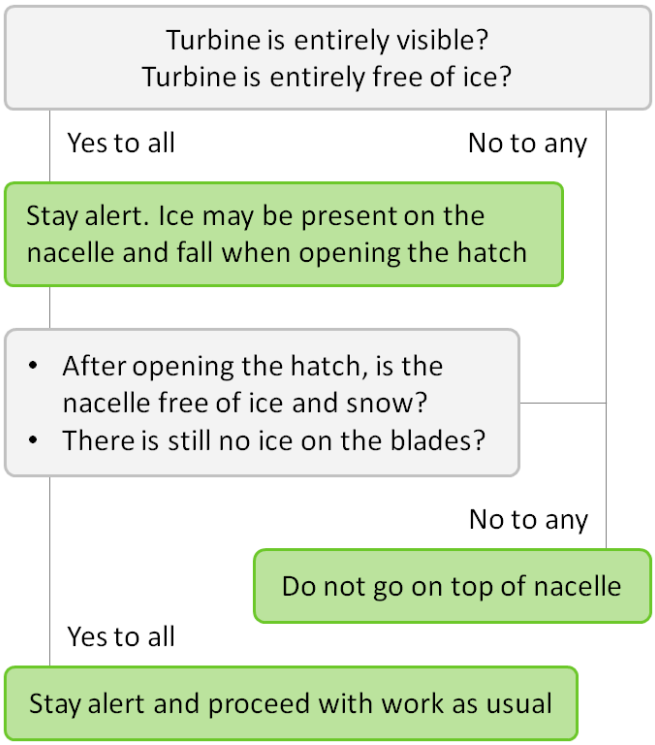
Table 18 presents the best practices regarding O&M at upper tower decks and nacelles.

Table 18: Best practices related to up tower and nacelle work for wind farm O&M in cold climate areas

Hoisting and Rigging

- Respect the procedure used in warmer conditions
- Ensure that all equipment temperature ratings are adequate for the actual air temperature | do not consider wind chill (service lift, ladder, railing, PPE and communication system, tools, etc.)
- Refer to section 0
- Ensure good foot positioning

Falling Ice Into/On Top of Nacelle



Hub.

Table 19 presents the best practices regarding O&M within a turbine rotor hub in cold climate areas.

Table 19: Best practices related to turbine hub work for wind farm O&M in cold climate areas

Nacelle to Hub Transfers

- Be careful to avoid slipping, tripping, and falling
- Three (3) points of contact at all time
- If there is ice, or the presence of ice cannot be assessed, do not transfer outside

Hub Work

- Plan your work (time to complete the task, time to get to the hub, warm up schedule, etc.)
- Make sure to leave yourself enough time to get to a warm location (it takes time to transfer from the hub to the nacelle and down tower)
- Respect the personal warm up schedule
- Be careful to avoid slipping, tripping, and falling
- Be careful not to get frostbite and hypothermia since limited space restricts movement and physical activity
- Wear proper clothing for the temperature and respect the warm up schedule
- Bring hot pads, as the cold reduces flexibility and dexterity

Best Practices Decision Tree

The next table (Table 20) presents the best practices in the format of a decision tree for icing and low temperatures. The first column contains the location where workers might have to perform O&M work on wind farms in cold climate areas. The second column enumerates main hazards related to the location. The list of hazards is not exhaustive. The final column details best practices for each hazard.

Table 20: Decision tree best practices

ICING		
Location	**Hazards**	**Best Practices**
Main roads	Reduced traction	• Vehicle inspection • Drive slowly • Weather assessment • Winter tires
	Reduced visibility	• Drive slowly • Turn on headlights
Service roads	Reduced traction	• Vehicle inspection • Drive slowly • Weather assessment • Winter tires
	Snow bank obstruction	• Do not try to drive over snow banks or snow drifts, as vehicle might get stuck • Remove the snow if possible • Postpone work until snow bank/drift has been removed
	Vehicle breakdown	• Ask for assistance • Seek/build shelter if vehicle does not have a cockpit (snowmobiles) and assistance is uncertain
	Reduced visibility	• Drive slowly • Turn on position lights • Stay on known terrain • Do not go close to turbines
	Stuck vehicle	• Ask for assistance • Pre-establish optimized procedures for each type of vehicle • Know the procedures • Do not spend too much energy trying to free the vehicle • Build/seek shelter while waiting for assistance if the vehicle has no cockpit • Do not keep the engine running unnecessarily
	Iced Turbines	• Do not enter any ice throw zones of iced turbines • If necessary, remotely shut down all the turbines with ice throw zones located near the route to the destination
Buildings on-site and parking lots	Snow/ice fall from roof	• Establish a security perimeter to ban access • Be careful when closing or opening doors since small vibrations can trigger the ice/snow to fall • Watch for increasing temperatures around 0°C
	Slips from iced pavement	• Watch for ice patches on the ground • Use additional points of support to increase balance • Use salt, sand or spiked snowshoes to increase traction
Vehicles	Ice fall and ice throw	• Park vehicles outside ice throw zones • Minimize the amount of time spent close to turbines
	Falling ice and snow from the vehicle when moving	• Remove snow on all surfaces on the vehicle • Remove ice from all windows, lights, and mirrors
Met. mast	Ice fall	• Stand outside the ice fall zone • Observe the mast with binoculars to assess the presence of ice • Do not approach if meteorological mast is iced
	Reduced visibility	• Do not enter the ice fall zone
	Ice fall and ice throw	• Evaluate the presence of ice before entering the ice throw zone

Vicinity of the turbines		– Ice detection methods (Power deviation, double anemometry, ice detectors) – Obtain previous meteorological conditions that might suggest that the turbine is iced (air temperature ranging from -5°C to 3°C, low cloud height, precipitation) – Check with previous work team (logbook, calendar or equivalent) – Watch for falling ice with binoculars • Document the information in a logbook, calendar or equivalent for the next work team • Evaluate the ice's stability • Is ice falling as turbine yaws and when it stops yawing? • Stand outside the ice throw zone if ice is unstable or if the presence of ice cannot be assessed • Remotely rotate the nacelle to position the blades at the opposite side of the access door • Stand outside the ice throw zone if the wind comes from the blades toward the access door • If the ice appears to be stable: – Turbine may be entered – Stay away from the blades – Do not approach alone – Name a spotter within the team that continuously observe for shedding ice – Get the vehicle as close as possible to the access door – Minimize the amount of time near the access door – After unloading the vehicle, it must be parked outside the ice throw zone – Use ice shed protection devices if applicable
	Reduced visibility	• Stay out of the ice throw zone as the presence of ice cannot be assessed
Down tower	Ice fall and ice throw	• Watch for falling ice when entering and exiting the tower • If ice appears unstable when exiting the turbine, stay inside • Minimize the amount of time outside • Get the vehicle as close as possible to the access door • Use ice shed protection devices if applicable
	Reduced visibility	• Stay inside if there are ice fall or ice throw hazards
	Frozen access door	• If the turbine is entirely free of ice, use antifreeze washer fluid to de-ice frozen areas of the door
Up tower and nacelle	Slips, trips, falls	• Do not go on top of nacelle if there is ice or snow • Safety shoe grip • Slow movements • Three (3) points of contact at all times when moving • Remove obstructions
	Reduced visibility	• Do not go on top of nacelle if it is not possible to assess the presence of ice on the blades
	Ice fall and ice throw	• Do not open the hatch if there is any ice fall or ice throw hazards • Do not go on top of nacelle if there is any ice fall or ice throw hazards
	Service hatch hoisting	• Ensure foot positioning • Do not place items on slippery surfaces near hatch • Ensure that the equipment is used in the appropriate temperature range
Hub	Transfers from nacelle to hub	• Be careful to avoid slipping, tripping, and falling • Three (3) points of contact at all times • If there is ice, or the presence of ice cannot be assessed, do not transfer outside
	Restricted space	• Be careful to avoid slipping, tripping, and falling • Be careful not to get frostbite and hypothermia since limited space restricts movement and physical activity • Wear proper clothing for the temperature and respect the warm up schedule • Bring hot pads as the cold reduces flexibility and dexterity

Low Temperatures		
Location	**Hazards**	**Best Practice**
Wind farm	Cold-related injuries	• Wear proper clothing • Select clothing according to the apparent temperature and the level of activity • Avoid getting wet by sweating • Put on multiple layers • The outside layer must be waterproof, windproof, and visible • Wear wool instead of cotton when possible • Warm hat with ear protection • Mittens instead of gloves when possible • Woolen socks (carry extra pair) • Insulated safety boots (carry extra safety shoes for indoor work) • Face mask for cold winds (no scarfs as it can get stuck in ladder and winch). • Respect your limit • Work with the warm up schedule as a guideline • Be aware of wind chill • Protect your nose, ears, fingers, and toes
	Electrical equipment failures	• Use the equipment in its proper temperature range • Fully charge all electronic devices, as cold temperatures affect the batteries
	Frostnip	• Get to a warm location • Do not rub affected area
	Frostbite	• DO NOT attempt to rewarm the affected area on-site (if the tissues refreeze it may cause even more damage) • DO NOT rub area or apply dry heat • DO NOT allow the victim to smoke or drink alcohol • Check for signs of hypothermia and seek medical attention • Treat the person gently and monitor breathing • If possible, move the victim to a warm area • Remove wet clothing and gently loosen or remove constricting clothing or jewelry that may restrict circulation • Warm the person by wrapping them in blankets or by putting on dry clothing • Cover the head and neck • Warm the person slowly and avoid direct contact with heat • Loosely cover the affected area with a sterile dressing • Place sterile gauze between the fingers and toes to absorb moisture and to prevent them from sticking together • If the person is alert, give them warm liquids to drink
	Hypothermia	• Seek medical help immediately • Hypothermia is a medical emergency. Quickly transport the victim to an emergency medical facility. • DO NOT warm the arms or legs directly • DO NOT warm the person too quickly (e.g. do not use a heating lamp or soak in a hot bath) • Ensure that wet clothing is removed • Place the victim between blankets so the temperature can rise gradually. Be sure to cover the victim’s head. • Hot water bottles, chemical hot packs, or electric blankets may be used with caution. Wrap in a towel before applying and warm the center of the body. • Give warm, sweet drinks unless the victim is rapidly losing consciousness, is unconscious, or convulsing (avoid caffeine and alcohol drinks) • Perform CPR (cardiopulmonary resuscitation) if the victim stops breathing. Continue to provide CPR until medical aid is available. The body slows when it is very cold, and in some cases, hypothermia victims who appeared dead have been successfully resuscitated

Near the turbine	Cold tools	• Wear gloves or mittens (cold metal tools can cause frostbite very quickly)
	Exposure to wind	• Wear proper clothing • Windproof outside layer is essential • Cover the ears, neck, and face • Safety winter goggles • Be aware of the apparent temperature • Select the proper working/warm up schedule
	Warm shelters are far	• Bring electrical heaters • Bring hot pads • Bring hot beverages
In the turbine	Cold tools	• Wear gloves or mittens (cold metal tools can cause frostbite very quickly)
	Cold-related injuries	• Know first aid procedures • Respect warm up schedule and, most importantly, how you feel
	Warm shelters are far	• Plan your work (Time to complete the task, time to get to work area, respect the warm-up schedule) • Bring electrical heaters • Bring hot pads • Bring hot beverages
Vehicles	Hard to start	• Inspect batteries regularly • Bring jumper cables • Know and respect procedures to boost vehicles (batteries can explode)
	Breakdown	• Warm up vehicle a few minutes before moving • Ask for assistance • Build/seek shelter if the vehicle has no cockpit (snowmobiles)

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Appendix A

Each province and territory has their own regulatory requirements regarding occupational health and safety. This appendix presents the contact information of the Canadian Centre for Occupation Health and Safety (federal legislation) and each province and territory's equivalent (provincial/territorial legislation).

Federal Legislation

Canadian Centre for Occupational Health and Safety
135 Hunter Street East
Hamilton, ON L8N 1M5
Phone: 905-570-8094 (8:30 AM to 5:00 PM EST Time)
Toll free: 1-800-668-4284 (Canada and US only)
Fax: 905-572-4500
Email: clientservices@ccohs.ca

OSH Answers Website: www.ccohs.ca/oshanswers
Website: www.ccohs.ca
General Contact: Phone: 905-572-2981, Fax: 905-572-2206

Provincial and Territorial Legislation

Alberta

Workplace Health and Safety
Alberta Human Resources and Employment
10030 – 107 Street, 10th Floor, South Tower, Seventh Street Plaza
Edmonton, AB T5J 3E4
Phone: 780-415-8690 (Edmonton and surrounding areas)
Toll free in Alberta: 1-866-415-8690
Fax: 780-422-3730
Email: whs@gov.ab.ca
Website: www.gov.ab.ca/hre/whs/

British Columbia

WorkSafeBC (Workers' Compensation Board of British Columbia)
6951 Westminster Highway (Richmond, BC)
PO Box 5350 Stn Terminal
Vancouver, BC V6B 5L5
Workplace Safety and Health Inquiries
Phone: 604-276-3100
Toll free in B.C.: 1-888-621-7233 (SAFE)
Fax: 604-244-6490

Health and Safety Emergency and Accident Reporting
Toll free in B.C.: 1-888-621-7233 (SAFE)
After hours: 1-866-922-4357 (WCB-HELP)
Website: www.worksafebc.com

Manitoba

Workplace Safety and Health Division Manitoba Labour and Immigration
200 – 401 York Avenue
Winnipeg, MB R3C 0P8
General Inquiries: 204-945-3446
Toll free in Manitoba: 1-800-282-8069
After hours: 204-945-0581
Fax: 204-945-4556
Email: wshcompl@gov.mb.ca
Website: www.gov.mb.ca/labour/safety/

New Brunswick

Workplace Health, Safety and Compensation Commission of New Brunswick
1 Portland Street, PO Box 160
Saint John, NB E2L 3X9
Phone: 506-632-2200
Toll free: 1-800-222-9775 (NB, PEI, NL, QC, ON)
Email: prevention@whscc.nb.ca
Fax: 506-633-3989

Health and Safety Emergencies
Toll-free: 1-800-442-9776
Email: prevention@whsccnb.ca
Website: www.whscc.nb.ca

Newfoundland and Labrador

Occupational Health and Safety Division Department of Government Services
15 Dundee Avenue
Mount Pearl, NL A1N 4R6
General Inquiries: 709-729-2706
Toll free in NL: 1-800-563-5471
Fax: 709-729-3445

Serious Workplace Accident Reports
Phone: 709-729-4444 (24 hours)
Website: www.gs.gov.nl.ca/ohs/

Northwest Territories and Nunavut

Workers' Safety and Compensation Commission of Northwest Territories and Nunavut
PO Box 8888
Yellowknife, NT X1A 2R3
General Inquiries: 867-920-3888
Toll free: 1-800-661-0792
Fax: 867-873-4596
Email: yellowknife@wcb.nt.ca
Website: www.wcb.nt.ca

Workers' Safety and Compensation Commission of Northwest Territories and Nunavut
Iqaluit
PO Box 669
Iqaluit, NU X0A 0H0
Phone: (867) 979-8500
Fax: (867) 979-8501
Toll free: 1-877-404-4407
Email: iqaluit@wcb.nt.ca
Website: www.wcb.nt.ca

Nova Scotia

Occupational Health and Safety Division Nova Scotia Department of Environment and Labour
5151 Terminal Rd., 6th floor, PO Box 697
Halifax, NS B3J 2T8
General Inquiries: (902) 424-5400
Toll free in NS: 1-800-952-2687
Fax: 902-424-5640
Email: webster@gov.ns.ca
Website: www.gov.ns.ca/enla/ohs/

Ontario

Ministry of Labour Occupational Health and Safety
655 Bay Street, 14th Floor
Toronto, ON M7A 2A3
General Inquiries: 416-326-7770
Toll free in Ontario: 1-800-268-8013
Fax: (416) 326-7761
Email: webohs@mol.gov.on.ca
Website: www.labour.gov.on.ca/english/index.php

Prince Edward Island

Workers' Compensation Board of PEI Occupational Health and Safety
14 Weymouth Street, PO Box 757
Charlottetown, PE C1A 7L7
General Inquiries: 902-368-5680
Toll free (in Atlantic Canada): 1-800-237-5049

Occupational Health & Safety 24 HR Emergency
Tel: 902-628-7513

Customer Liaison Service: 1-866-460-3074
Fax: 902-368-5705
Website: http://www.wcb.pe.ca

Québec

Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST)
1199, rue de Bleury, C.P. 6056
Montréal, QC H3C 4E1
Tel: 514-906-3780/514 906-3061, ext. 2214
1-866-302-2778
Fax: 514-906-3781/514 906-3016

24-hour service – Services de prévention-inspection : (514) 906-2911
Website: http://www.cnesst.gouv.qc.ca

Saskatchewan

Saskatchewan Labour Occupational Health and Safety Division
400 – 1870 Albert Street
Regina, SK S4P 4W1
Phone: 306-787-4496
Toll free in SK: 1-800-567-7233
Fax: 306-787-2208
Website: http://www.saskatchewan.ca/business/safety-in-the-workplace
Office: 122 – 3rd Avenue North
Saskatoon, SK S7K 2H6
Phone: 306-933-5052
Toll free: 1-800-667-5023
Fax: 306-933-7339

Yukon Territory

Yukon Workers' Compensation, Health and Safety Board
Occupational Health and Safety Branch
401 Strickland Street
Whitehorse, YT Y1A 5N8
General Inquiries: 867-667-5645

24-hour Emergency Line for Reporting Serious Workplace Accidents and Injuries: (867) 667-5450
Toll free across Canada: 1-800-661-0443
Fax: 867-393-6279

Workplace Accidents and Injuries
Phone: 867-667-5450 (24 hrs)
Email: worksafe@gov.yk.ca
Website: www.wcb.yk.ca