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Recommendations for communicating risk of ice throw/fall in Norwegian wind parks

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Photo by Statkraft: Wind turbines in winter landscape, Kjøllefjord, Norway

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Abstract

This report is written as part of Work Package 4 in the project Wind Energy in Icing Climates. The aim of this report is to address some key challenges in the current ways ice-throw/fall hazards are communicated about and how this communication can be improved in Norwegian wind turbine parks, especially when aiming to inform (potential) non-expert users. The research and findings presented in this report have been guided specifically by the following questions:

1. *How can the application of online information channels for ice-throw/fall risk be improved, as to optimally communicate risk information (CAP warnings, impacts, behavioural advice), facilitate wind park operators in their communication with potential visitors to the park and give 'actionable' risk information to users?*
2. *Which measures can enhance the communication of primary risk information (CAP warnings, impacts, behavioural advice), such that it helps people to build skills and awareness needed to minimize risk of injury when entering Norwegian wind turbine parks?*

A brief literature review has been conducted, along with qualitative interviews (wind park personnel and municipality representative) and a quantitative survey (general public). This report contains the main results coming out of these activities.

The findings presented in this report indicate that in the Norwegian context, even though the number of visits may be limited, there is a need for providing information/warnings abouts possible ice-throw/fall conditions for those who plan to visit wind turbine parks. The results form the foundation of a list of recommendations, which are outlined in the final section of this report.

Keywords

Risk communication, ice throw/fall, Norwegian wind parks

Disciplinary signature

Responsible signature

Summary

This report is written as part of Work Package 4 in the project Wind Energy in Icing Climates. The aim of this work package was to develop recommendations for communication of the risk of ice-throw/fall from turbines in Norwegian wind parks. A brief literature review has been conducted, along with qualitative interviews (wind park personnel and municipality representative) and a quantitative survey (general public). This report contains the main results coming out of these activities. The results form the foundation of a list of recommendations, which are outlined in the final section of this report.

The current state of knowledge about best practices for ice throw/fall risk communication is still in an exploratory phase, and empirical research on this is fragmented. The main attempt toward a consolidation of best practices in ice throw/fall risk communication has been part of the IEA Wind TCP Task 19 work. A recent request from NVE pointed to the need for improved warning communication for ice throw/fall in twelve Norwegian wind turbine parks. On the one hand a set of best practices related to safe operations of wind parks exists, highlighting specific safety procedures aimed towards wind park personnel. To avoid accidents or fatalities caused by ice throw/fall there is also a need for a warning system and communication to the public. There is, however, no best practice in how to do this. Literature and empirical evidence related to communication of weather warnings can be useful input to the context of ice throw/fall risk. For example, the colours used in the warnings are important, because they will most likely influence people's decisions about visiting the wind park or not.

A first step in this work package was to speak with wind park personnel about daily handling of ice throw/fall risk in their daily routines. In addition, we spoke with a researcher working with the modelling of ice-throw risk and a person employed in one of the municipalities where some of the wind parks are located. Through the interviews we were able to map the existing communication and how the risk of ice throw/fall is handled today. We soon learned that the maintenance personnel have formal procedures they follow to handle and mitigate the risk for injury and damage from ice throw/fall. Into these procedures, maintenance personnel have built a set of specific skills that appear to be useful when they plan to approach a turbine in the winter season. Some of the wind parks use a common format for communicating the risk of ice throw/fall, but little is known about the use of the information on these websites (e.g., the warning colours). Partly, this is because there appear to be very few leisure visitors to the wind parks in the winter season. Importantly, if they are not frequently visiting the park, it is not likely that they have specialized experience assessing the risk of ice throw/fall. Hence, it is essential

to learn more about how the different warning colours and behavioural advices are understood and used by potential visitors.

Next to the series of interviews with experts, which were aimed at getting a generic overview of current routines and challenges around ice-throw/fall risk communication practices, a quantitative survey was conducted to gain insights about the perceived value of different communication tools and formats for ice throw/fall among the Norwegian public. One main finding from the survey was that warning information on ice throw/fall is appreciated, and appears to be overall understandable and actionable. The tested CAP format for ice throw/fall warnings appears to be suitable for communicating the risk related to ice throw/fall. However, fine-tuning the combination of colours and guiding text requires systematic testing, in order to arrive at a format that is actionable, while not risking information overload. Although higher risk levels (for example red colour) appear to trigger people's attention to information and to process the information more actively, we found that people lack the skills to perform observations such as listening to the sound of the turbines or assessing the safety distance to the turbines.

Since the context of visiting a wind park will be a new experience to many people, they may need further assistance to make informed decisions. One way to do that is by communicating the consequences and advice related to the different warning colours through a consistent portfolio of channels. A second way is to facilitate the building of skills that are currently often used by maintenance personnel, as to recognize through cue observations potentially hazardous conditions.

We provide a set of recommendations around these two qualitative measures (Chapter 3) which should contribute to improved risk communication practices for wind parks in Norway. The recommendations include the following, listed for the three main topics:

Enhancing risk information accessibility (RQ1)

A consistent portfolio of communication channels

1. Channels used for ice throw/fall risk communication should ideally consist of a portfolio of multiple outlets, including both physical signs in/around a wind turbine park, and websites;
2. The channel portfolio used should be built on the premise that at least part of the channels is trusted by the intended audience, and regularly consulted by them (for example, Varsom.no);
3. The channel portfolio should be consistent in its messages, which allows for people to create a confirmative impression of the risk situation, and how to cope with it;

4. Consistency across channels also implies a recognizable format across both physical and digital channels (see also the recommendations about information formats);
5. The portfolio of channels should provide options for consulting both weather information and current ice throw/fall risk information at moments/places where people tend to make a behavioural decision that may affect their exposure to ice throw/fall risks. For example, physical signs at a parking area may include a website URL or a QR code that brings people directly to the latest online risk information.

Accounting for different levels of risk (un)familiarity

1. Familiarity with available risk information channels among potential user groups should be nurtured, for example by an annual awareness campaign;
2. Communication of unfamiliar risks may benefit from using the sources that (potential) users are able to find. Therefore, wind park operators aiming to communicate ice throw/fall risk information should connect with the (digital) channels available on the national and regional levels (including local media), next to using their own websites;
3. People appear relatively familiar with weather-related risk information, and many have adopted a routine around consulting weather forecasts on a daily basis. Framing the ice throw/fall as a weather hazard, as opposed to a technical hazard, may improve understanding and uptake.

Information formats (RQ2)

CAP format as template for ice throw/fall warnings

1. Online warnings for ice throw/fall may adopt the CAP format, as to be consistent in their content across wind park contexts, and consistent with a globally supported format for warning communication;
2. Online warnings for ice throw/fall are recommended to put a consistently used (similar to all relevant Norwegian wind parks) warning colour scheme as a central ingredient;
3. Online warnings for ice throw/fall should avoid overloading their intended audiences with information that attenuates understanding and, consequently, behavioural action. It is therefore recommended to:
    - Layer warning information according to the model proposed by Popovic et al. (2021) (see Figure 3, section 1.2.3);
    - Use the warning colours as main tool to create awareness of the risk level
    - Clearly explain the meaning of each colour level (risk versus probability);
    - Make a clear distinction between ‘no risk’ and ‘low risk’ (green level);

    - Use text and/or graphics to inform about impacts and advice (see 3.2.2);
4. Online warnings should be primarily formatted to tailor non-expert audiences, since expert users (cf. maintenance personnel) may best be catered through other channels that allow for integration into Standard Operating Procedures;
5. Additional information that is made available online, which is aimed at conveying insights about on-site skills to assess conditions should complement the warning information. However, to avoid information overload this information may best be presented on a separate page or in a second layer (cf. layering, see also 3.2.2).

Impact information and behavioural advice

1. Indications for distance to a wind turbine are to be clearly communicated and available within a wind turbine park. Next to the need to address individual skills (see 3.3), this may require innovative technological solutions (augmented reality, location-based alerts);
2. Any warning level (including a no risk situation) should be accompanied by clear behavioural advice for how to stay safe from harm by potential ice throw/fall;
3. Background information about ice throw/fall phenomenon may be included on both physical signs and online, but to avoid cluttering of information this should be clearly separated from the actual warning information (cf. layering).

The long-term perspective: building actionable information

Observation skills

1. Facilitate interaction with wind turbine park personnel and local actors (municipalities, leisure organisations) to co-develop an awareness programme that facilitates the development of individual skills to observe and recognize cues that signify potentially hazardous icing conditions;
2. Target awareness programs to specific user groups that are most likely exposed, where possible. Examples of such groups are reindeer herders or recreationists in ski areas;
3. A flyer has been developed with tips for safe access of wind turbine parks during winter. The objective of the flyer is to inform and create awareness (Vindvett, a sense for wind). It is recommended to consider expanding the Vindvett concept to an online webpage that provides a list of short videos, for example featuring wind turbine maintenance personnel that explains specific methods for assessing icing conditions.

Monitoring perceptions and behaviours

1. Set up a methodology for continuous monitoring of:
    - Impacts of changes in the risk communication practices;

- Risk perceptions for ice throw/fall;
- Behavioural activity in wind turbine parks, and possible change over time.

2. Methods and tools to be considered include:
    - A two-yearly quantitative survey among the Norwegian public, based on the quantitative survey reported in this document;
    - Case studies in selected wind parks, to test best practices for warning communication;
    - A (national) expert committee on risk communication for ice throw/fall that includes representatives of key Norwegian user groups.

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1 Introduction

1.1 Background

Accumulation of ice and snow on wind turbines brings with it a risk of injury for anyone in the vicinity of a turbine, due to the possibility of ice or snow being thrown off turbine blades or falling down from the turbine. Risk management in wind turbine parks situated in climates favourable to icing conditions have been concerned with assessing these risks, minimizing the potential of adverse impacts, and developing risk communication tools to inform those who are (potentially) exposed.

Much work has been done to model and quantify the risk of ice-throw and ice-fall from wind turbines, and to develop criteria that provide a basis for safe construction and maintenance of wind turbine parks. Initiatives such as IEA Wind TCP Task 19 and various regional projects have advanced the risk management of ice-throw across the world. There is still a need to better understand how icing risk can be communicated in ways that adequately inform those who need or wish to access areas where wind turbines are located. The work reported in this document is part of the project 'Wind Energy in Icing Climates'. The Norwegian Meteorological Institute has led and executed activities under a work package of this project, with the specific aim to develop recommendations for communication of the risk of ice-throw/fall from turbines in Norwegian wind parks.

A key objective of the project tasks that led up to this report has been to contribute to a systematic knowledge base that can inform the qualitative measures, as described in Paragraph 4.3.3. of the International Recommendations for Ice Fall and Ice Throw Risk Assessments (IEA Wind TCP Task 19, 2018). Such qualitative measures (Figure 1) are needed to mitigate risk from ice-throw and ice-fall, but "cannot be assessed quantitatively, [and therefore] should be considered independent from the measures discussed [in other sections of the report]" (p.26).

Category	Safety measures	Remark
Awareness of residents	Communication strategy	Independent from the calculated risk, these measures should be taken to inform the residents and - as a long-term strategy - change their behaviour.
	Regular education to change behaviour of people.	

Figure 1. Suggested qualitative measures for ice throw/fall risk mitigation

Thus, in the following sections we outline a summary of the current state of knowledge about risk communication for ice throw/fall, and embed this in the broader context of environmental (i.e., weather) risk communication practices. We build on best practices in warning communication that have been developed in the weather community. The section also provides context for the need to establish a systematic set of recommendations for communication of ice throw/fall risk for wind turbine parks located in Norway. We hereby develop a rationale for the activities and findings presented in the remainder of this report.

1.2 Risk communication practices

1.2.1 Ice throw/fall risk management

With an increasing number of wind turbine parks being built across many countries, possible risks related to exposure of societal actors are becoming an essential factor to address through risk management. The potential of ice or snow accumulating on turbines is especially a concern at higher latitudes, and is therefore of interest to wind turbine operators in Nordic countries, including Norway. Next to its potential impact on turbine performance efficiency, accumulated ice and snow poses a risk to anyone in proximity of a turbine, when the ice or snow is falling from the turbine or propelled away from the turbine blades. Risk management for wind turbine parks has become highly standardized in terms of calculating acceptable risk criteria, but so far, the communication of possible risks and their consequences for societal actors has not evolved into a validated set of best practices. The current state of knowledge about best practices for ice throw/fall risk communication is still in an exploratory phase, and empirical research on this is fragmented. The main attempt toward a consolidation of best practices in ice throw/fall risk communication has been part of the IEA Wind TCP Task 19 work[1]. Its mandate is to provide international guidelines for ice risk assessment. A report that was published in 2018 (Krenn et al., 2018) is currently being updated.

Bredesen, Drapalik and Butt (2017) provide a framework that should underlie the guidelines as developed in IEA Wind TCP Task 19 (Krenn et al., 2018). Next to various technical factors, for example around ice accretion calculations and ice throw trajectories modelling, they include a risk communication approach that is founded on three assumptions (based on the classical likelihood*consequences definition of risk). The first assumption is that regardless of the actual risk, there are always some consequences that are not acceptable. For example, this means that even when ice throw risk models use

[1] https://iea-wind.org/task19/

quantitative criteria such as LIRA (Localized Individual Risk per Annum), in practice there should never be any fatality resulting from ice throw events. Second, systematic risk management, and the related risk communication practices, should be embedded in a quantification of possible consequences and probabilities. Third, communication of risk should be based on knowledge about the possible impacts. In the context of risk for ice-throw/fall, current risk management is based on a so-called Vision Zero policy, meaning that there should be (nearly) no fatalities or injuries resulting from ice throw/fall occurrences. In practice this means that even in wind turbine parks with a theoretical low likelihood of icing, risk management needs to include a comprehensive risk communication plan.

In theory, any wind turbine that operates in an icing climate can be subject to ice-throw/fall. In practice however, major variations are observed in the actual occurrence of ice throw/fall events, depending on a complex combination of local factors (from the design of the wind turbine, to orography, to the prevailing microclimate in the area where wind turbines are located). In general, icing load grows exponentially with height above sea level[2].

To arrive at a comprehensive and functioning risk communication plan that fits both standardization on the (inter)national level as well as allows for adjustments to local contexts, it is important to not only rely on risk models and quantified criteria. Risk communication is best seen as a multi-direction practice (see for example Ping et al., 2016), where involvement of the public into the realization of safety measures is a key factor for successful communication (Höppner et al., 2012). A challenge with risk communication for ice throw/fall is that the phenomenon itself is largely unfamiliar to many. This makes it difficult both to convey the actual risk, as well as to ensure that those who are possibly exposed to it are aware of the risk take the right precautions and protective measures. Along this line, Bredesen et al. (2017) recommend that "in addition to the detailed planning of the actual wind parks, designed signs and warning routines, possible sound and light signals, direct warning systems (e.g., SMS/app), and detection systems it is recommended to establish public knowledge about the risk and to consider physical safeguards and/or curtailment options (e.g., to stop the turbine during periods of particularly high risk." (p.17).

In the Norwegian context, Bredesen et al. (2017) refer to a collaboration with the Norwegian Water Resource and Energy Directorate (NVE) to develop risk management

[2] http://winterwind.se/wp-content/uploads/2015/08/3_3_28_Bredesen_IEA_Task_19_-_IceRisk_Review_of_current_knowledge_and_the_way_forward_in_risk_assessments_associated_with_ice_throw_from_wind_turbine_blades_Pub_v1-1.pdf

guidelines for Norwegian wind turbine parks[3]. These efforts are ongoing, and a recent request from NVE included pointed to the need for improved warning communication for ice throw/fall in twelve Norwegian wind turbine parks[4].

1.2.2 Ice risk communication: current knowledge

The publication by Bredesen, Drapalik and Butt (2017) is one of relatively few studies concerning ice risk communication. All wind turbines operating in an icing climate introduce the hazard of ice throw or icefall on the nearest surrounding area although with highly varying frequency and probability. The risk of ice throw is highest during icing and melting conditions but can persist well beyond for several hours/days. Bredesen, Drapalik and Butt (2017) point to establishing good practices and communication routines as key to avoid accidents. This means that there is a public requirement of warning systems for the risk of ice throw. Moreover, according to Bredesen, Drapalik and Butt (2017) it has been a challenge to get the warning to be respected; highlighting the need to achieve good communication. Risk communication is classically seen in a one-way direction, experts inform the concerned public. This may result in additional opposition and little understanding amongst intended audiences. Thus, an early involvement of the public in project realization and application of safety measures is highly advisable. However, the responsibility for avoiding accidents lies not only on the wind park. There is also a personal responsibility for third-persons to respect signs and warning systems, assuming they are reasonable, i.e., well designed and only actively warn when there is a danger.

We find two relevant publications from North-America related to communication of risk of ice in wind parks. One of them is published by the Canadian Wind Energy Association, and gives best practice guidelines related to safe operation of wind parks in cold climates (Canwea, 2017). These guidelines are meant to be a tool to help assist with management of health and safety, and seem to be primarily aimed towards wind park personnel (not external visitors). Since every site is unique (terrain, buildings, access), other practices or a combination of practices other than those presented here might be more suitable. Besides properly rated equipment and proper clothing, a general best practice is to plan your work (check weather/forecast, evaluate the probability/presence of ice on site, assess the severity of consequences etc.). Specific safety procedures are highlighted as important in respect of any icing that may occur. These procedures include flow charts for turbine

[3] https://www.nve.no/nytt-fra-nve/nyheter-konsesjon/ny-veileder-for-handtering-av-faren-for-iskast-fra-vindturbiner/
[4] https://www.nve.no/nytt-fra-nve/nyheter-tilsyn/varsling-av-fare-for-iskast-fra-vindturbiner-ved-12-vindkraftverk-ma-forbedres/

approach (Figure 2) where, for example, meteorological conditions (e.g., low temperatures) and visual cues of ice (iced turbine/nacelle) should be assessed.

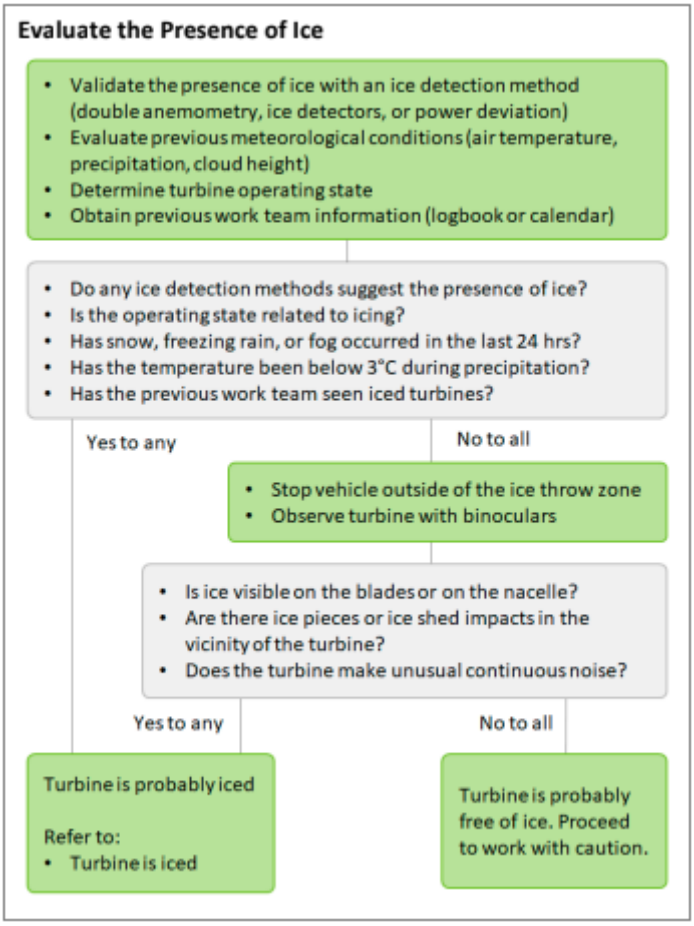

Figure 2. Flow chart for turbine approach from the Canadian Wind Energy Association (Canwea, 2017).

Although not an exhaustive collection of all information to ensure complete safety for the public, some practices concerning public safety are provided in the report. One possibility is to restrict access (fences) to the wind park. Another possibility is to use danger warning signs. Such signs must be visible and placed strategically, e.g., related to recreational activity trails (snowmobile, skiing). In addition, public information on websites or shutdown during icing events are mentioned as possible practices to keep the public safe.

Another relevant publication from North-America is a PhD thesis, studying wind turbine ice throw hazards among wind park personnel and community stakeholders, in Texas, USA (Klaus, 2017). Ice throw from wind turbines poses a significant risk not only to the

surrounding community but also to those who work every day at these wind parks in performing routine maintenance. Being struck by an ice fragment is a low probability - high consequence event. While 75 percent of operations and maintenance personnel in the study had witnessed an ice throw incident from a wind turbine, a majority of the community stakeholders had never witnessed an ice throw incident, with only seven participants having ever witnessed an event. The hazard is not generally known to the public, as there has not been a significant event in the USA which has drawn any media attention. However, as new turbines are continuously installed, the number of people exposed greatly increases, and Klaus (2017) speculates that it is only a matter of time before the industry suffers a severe incident or even a fatality.

Both wind park personnel and community stakeholders were asked about preferences for warning communication. The community stakeholders ranked TV news as the best warning system for communicating falling ice from wind turbines, followed by warning signs. The website of wind park companies was cited as the least preferred warning system. The employees in the wind parks put signs as the preferred way to communicate the risk of ice, but only 2% of the community stakeholders knew if the parks used signs to communicate the risk. Interestingly, the employees ranked the local TV news as the worst warning system.

According to Klaus (2017), the risk literature indicates that environmental cues, such as weather conditions, observing ice on wind turbines, or hearing ice cracking or falling will elicit protective action. 93 Percent of park personnel issued stand-down orders or suspended field work in response to such cues. The community stakeholders' response was to stay away or keep their distance from turbines.

To summarize, on the one hand a set of best practices related to safe operations of wind parks exists. Here, specific safety procedures are highlighted as important. Amongst others, these procedures include assessing meteorological conditions and visual cues. Nevertheless, they are aimed towards wind park personnel, and to avoid accidents or fatalities caused by ice throw there is also a need for a warning system and communication to the public. To be respected, these warnings should be reasonable and well designed. There is, however, no best practice in how to warn the public, with physical signs, websites, and TV news are all mentioned as possible platforms.

1.2.3 Environmental risk communication: actionable information?

There is an extensive body of literature and empirical evidence related to communication of weather warnings, and several of the publications have findings and recommendations

that can be useful and possibly transferred to the domain of ice-throw risk communication. The recently published studies that are referred to below build on a significant body of empirical research and literature. However, since the objective of this report is mainly to provide tangible recommendations, a more extensive literature review is beyond the scope of this report.

Popovic et al. (2021) study in Switzerland how different elements of a warning message (see Figure 3) influence spontaneous reaction to the warning, and intended behavioural change. Specifically, they study which elements are most important to serve as a 'wake-up call' and hence should be most visible in the warning communication. In line with the findings of Weyrich et al. (2018), Popovic et al. (2021) found that potential impact and/or recommendations for action have the strongest effect on intention to act, and for that reason should be displayed prominently in a warning message. Moreover, the perceived risk and the perceived personal relevance apparently play an important role in people's intention to act, and should be addressed in the design of the warning message. For example, the recommendations for action can be categorized by activity or location to increase personal relevance, and rather than using labels like "great danger", information on what might actually happen can be provided. In turn, the meteorological parameters were suggested in Popovic et al. (2021) to be shown in a second layer.

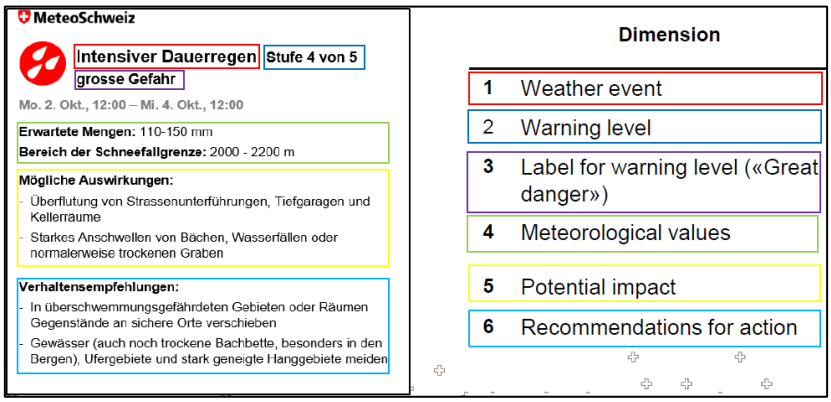

Figure 3: The different elements in the warning message used in the Swiss study (Popovic et al., 2021).

These findings are from scenario-based experiments, and it has been questioned how well they reflect real life behaviour, especially since the experiments will not evoke as strong feelings as in real life events. However, in a comparison between a field experiment to investigate actual responses and an almost identical scenario-based experiment, Weyrich

et al. (2020) found that warning messages were perceived and understood in very similar ways.

Another (unpublished) survey on weather warnings was conducted by NRK/Yr in Norway in May 2021. The survey, catered for Yr users, received an answer from approximately 30.000 respondents. In this survey, the respondents were generally well known with the warnings on the Yr.no website (when asked how familiar they are with the warnings shown on Yr, 71% answer 3 or 4, 15% answer 5, on a scale from 1-5 where 5 is the highest score). However, be aware that not all respondents know which warning colours are used; for example, 18% answered green, yellow and red (traffic light, which might be a typical mental model), and did not include orange in their responses. This means that the full scale is not intuitively known to all users if they see only one warning (colour). Thus, it can be important to display the scale that is used.

Furthermore, the Norwegian survey examined how people understand the seriousness of the event based on the warning colour, and if the warning levels trigger the desired responses. When asked, 94 percent answered that they think a red warning is more serious than orange and yellow warnings. To use red colour to indicate stop or danger and green colour to indicate go-ahead is almost universal (e.g., traffic light, customs), and might even have evolutionary roots (Association for Psychological Science, 2011). In Figure 4 we can see the terms most frequently related to the different warning colours. Also here, green is commonly associated with “no (danger)” and “safe”, and red is associated with “serious” and “extreme”.

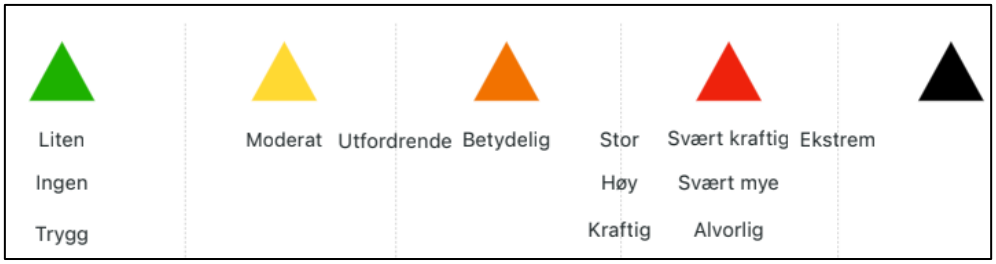

Figure 4: Terms associated with the different warning colours (Source: NRK/Yr).

With increasing warning severity levels, more respondents answered that they check the forecast/warning more frequently and consult various sources. They discuss with others, think about their safety, and avoid certain activities/stay home. 29% answer that the colour must be at least yellow before they read the full content of the warning, 22%

answer orange, and 10% red. Some people read the full content just because they are curious, or plan for a hike etc. This means that it is likely that an increasing warning level leads more people to spend more time searching for information before they make their decisions, because more is at stake.

1.3 Aims and methods

1.3.1 Research questions

The research activities and findings presented in this report are guided by the following two questions:

1. *How can the application of online information channels for ice-throw/fall risk be improved, as to optimally communicate risk information (CAP warnings, impacts, behavioural advice), facilitate wind park operators in their communication with potential visitors to the park and give 'actionable' risk information to users?*
2. *Which measures can enhance the communication of primary risk information (CAP warnings, impacts, behavioural advice), such that it helps people to build skills and awareness needed to minimize risk of injury when entering Norwegian wind turbine parks?*

Given the limited existing empirical evidence about current risk communication practices, including in the context of Norwegian wind turbine parks, the research reported here has a strong exploratory character. The aim of this report is thus to contribute to building a systematic knowledge base around the current ways ice-throw/fall hazards are communicated about and how this communication can be improved, especially when aiming to inform (potential) non-expert users.

1.3.2 Methods

To arrive at new insights that can answer the above questions, and to provide recommendations for improving communication of ice throw and ice fall risks, a multi-method approach was employed consisting of a qualitative stage, and a quantitative stage.

The qualitative stage was initiated in November 2020, and lasted until February 2021. This stage consisted of a series of semi-structured interviews with experts around the construction and maintenance of wind turbine parks. Qualitative insights were gathered from a variety of perspectives, including those of personnel responsible for turbine maintenance, and of local municipalities in which wind turbine parks are located. In total

five persons were interviewed. The interviews covered a selected number of topics around risk management practices, risk communication and use/access of wind turbine areas (See Appendix B for interview schedule).

A subsequent quantitative stage featured a survey that was aimed at getting insight in perceptions of the general public about ice-throw risk, and to explore the impact of warning formats to be used for future communication of icing hazards. The survey was based on insights gained during the qualitative stage, combined with scientific knowledge from the broader scientific field of environmental risk communication, and in-house knowledge of best-practices on warning communication at MET Norway.

1.3.3 Limitations and challenges

The work package activities were taking place during the COVID-19 pandemic, and were significantly impacted by the restrictions imposed on travel and physical meetings. All the data collection activities, including interviews during the qualitative stage, were conducted online. While the quality of the data collected during these interviews includes important insights, the number of interviews has arguably remained low due to these restrictions. For example, it has not been possible for the authors to travel to existing wind parks, and gain first-hand observations, meet with local stakeholders or enquire directly with residents living in the area surrounding wind turbine parks.

In addition, wind turbine parks are currently subject of highly charged debates about topics related to land-use planning, ecology, renewable energy, indigenous rights and other issues. It is the impression of the authors that these ongoing debates have complicated the data collection and the project task proceedings, especially with regard to gathering insights from multiple stakeholders. A large number of attempts to arrange interviews remained unanswered, or ended up in people declining the invitation.

A final limitation affecting the data collection pertains to the minimal number of people accessing wind turbine parks in winter, thus resulting in a situation where the actual exposure of people to risk for injury from ice-throw/fall is mostly on the basis of potential use.

2 Communicating & handling ice-throw/fall risk: findings

This chapter contains the main findings from the pursued research activities. The chapter first discusses the key themes discussed during the expert interviews. These findings set the scene for the second part of the chapter in which the survey findings are outlined in detail.

2.1 Expert interviews: risk management practices

2.1.1 Setting the scene

The authors of this report had no prior experience with the context of wind turbine parks, nor with communication of ice-throw risk. Therefore, as a first step, to start speaking with people associated with the construction and maintenance of wind parks appeared a logical choice: daily handling of ice-throw and ice-fall risk being part of their working day routines provided a basic insight in the key issues and challenges related to handling and communicating ice-throw risk. Thus, through the interviews we were able to map the existing communication as well as how the risk of ice-throw and ice-fall is handled today. Also, via these experts, insights into who else may be accessing the wind parks should be available, hereby assisting us in including multiple perspectives.

Along this line, we reached out to wind park operators/managers to ask their permission to speak to personnel working in the wind parks. Wind park owners use subcontractors for maintenance of the wind turbines, and these technical personnel are the ones that need to handle the risk of ice-throw daily in the winter season. In addition, we spoke with a researcher working with the modelling of ice-throw risk (and the associated warnings). Finally, to get a better understanding of external use of the wind parks, we were speaking to a person employed in one of the municipalities where some of the wind parks are located. Key themes and relevant points taken from the interviews are summarized below.

2.1.2 Different user types

Already from the first interview session it became clear to us that the **maintenance personnel** have procedures they (are expected to) follow to handle and lower the risk of being hit by ice thrown from the wind turbine blades. The procedures are made such that

it should be a fast and reliable way for them to make the decisions on a (nearly) daily basis in the winter season. Combined with these procedures, the personnel have also built a set of situated expertise/skills that they rely on when they plan to approach a turbine in the winter season. Concretely these include i) to assess the weather conditions to better know when ice builds up (typically a combination of assessing the weather forecast (e.g., Yr.no website) and making own visual observations in the park), ii) to look for physical signs of existing ice on blades or ice recently thrown to the ground (e.g., use binoculars and flashlights to look for ice on the blades, traces of ice in the snow on the ground).

> *"We have a procedure on how to observe the turbine before we go. The risk is from leaving the car to entering the turbine."*
> *(Maintenance personnel)*

Overall, interviewees see a distinction between the degree that maintenance personnel and visitors of a wind turbine park can handle icing risk when being in an area with wind turbines. For example, the personnel have an alternative to either stop the turbine or to work remotely if the risk of ice throw is too high. In addition, they wear helmets and have a clearly defined purpose for which they enter a wind turbine park. Visitors on the other hand often have a fuzzier objective that is less related to the turbines, and therefore requires a different way of mitigating their exposure.

> *"It is a different kind of risk they can tolerate, and that is why we have two different ways of handling them - the people that live there, that use the ski resort, and the technicians that are going to perform service on the turbines."*
> *(Wind power researcher)*

Based on our talks with various experts, we have the impression that there are very few **leisure visitors** to the wind parks in the winter season. There are, however, exceptions. For example, close to one wind park (Ånstadblåheia) is a ski resort, and in another (Guleslettene) there are ski trails in the winter. Nevertheless, it appears that many wind parks are mainly accessed by leisure visitors in the summer, for example to enjoy a hike of for fishing. Then, the turbines can be seen as a natural destination, since they are located on hills and at the end of the roads. We have not been able to speak directly with (winter) leisure visitors, and can only assume that if they are not frequently visiting the park. However, it is not likely that leisure visitors have specialized knowledge/experience assessing the risk of ice throw. Also, the personnel in the parks we have spoken to are rarely contacted by external visitors. The perceptions around how attractive wind parks are for winter leisure remains a knowledge gap that is case-dependent and may be assessed within the context of each wind turbine park individually.

A special case in terms of local knowledge and wind park use is the **reindeer herders**. In some wind parks there is grazing land for reindeers, and the herders might need to walk into the wind park to look after the herd. Similar to the park personnel, it can be expected that the herders bring binoculars (to look after the herd). Thus, they might have certain skills that can help them assess the risk of ice throw from the wind turbines. Within the context of this project, we have not managed to get in touch with reindeer herders or their representatives.

Depending on the geographic location of wind turbine parks, there may be other interest groups that should be considered in the ice throw/fall risk communication. However, based on our interviews the above groups appear to be the main (potential) users of areas where wind turbines are located.

2.1.3 Perceptions about accessibility

A second theme that was discussed is accessibility. While wind turbine parks in Norway have no fences and **people are free to enter the parks**, there appear to exist different perceptions on how open the wind parks actually are for external use. For example, the impact of infrastructural interventions of wind turbine constructions can move the degree of accessibility in multiple directions. Some areas might have become more accessible after the wind parks, because of new roads. Still, some of the roads are closed for cars (except for landowners, cabin owners etc.), and it takes several hours to walk to the turbines. Thus, the new roads do not guarantee accessibility, and if people have other areas to hike or ski, they might prefer that. On the other hand, some actors might consider "wind park tourism" if the wind parks open up, since viewing the big turbines from nearby can be a spectacular experience.

One interviewee said that the wind park owners are concerned about the risk of ice-throw and injuries, and appear unwilling to open the park to visitors. According to what was reported to us, there is relatively little icing on wind turbine blades in Norway (e.g., compared to Sweden and Finland). Icing is experienced though, sometimes even in large amounts.

> *"I have seen large icicles on the nacelle, 1-2 meters long in extreme situations." (Maintenance personnel)*

However, perceptions around risk and accessibility are also related to ongoing legal conflicts between park owners and reindeer herders, and that the public debate about wind parks in Norway in recent years have become more polarized. While these factors do not

directly imply ice throw/fall risks, they reflect the 'larger forces' that are at play around the degree wind turbine parks may be open to the general public. Accidents in the wind parks might add fuel to these already **delicate and tense debates**. The potential risks related to icing are embedded in these discussions, and at least in some cases ice throw/fall surfaces as a decisive factor:

> *"We have agreements with them...about how accessible the wind parks should be to visitors. Ice throw is one of the arguments they (the park owner) use to restrict the accessibility."*
> *(Municipality representative)*

Finally, the expert interviews revealed perceptions about what can be seen as a difference between the theoretical risks and the actual risks. In other words, accessibility is not only a question of a wind turbine park being open or not. Accessibility is also reflected in the actual behaviour of (potential) visitors - is there a risk for injury if there are no visitors? As mentioned above, it seems that the parks are mainly used by leisure visitors in the summer season (e.g., cabins, hiking etc.), with little known wintertime usage. Thus, it should be possible to open up the parks for leisure activities when the weather conditions are right, also during the months where ice throw/fall is possible. Nevertheless, if approaching the turbines, the possibility of ice or snow on the turbine nacelles and the blades should be top of mind. Having at hand the necessary resources (skills and risk information) should play a decisive role in the extent to which wind turbine parks and individual wind turbines are accessible.

2.1.4 Online warning information

A number of Norwegian wind turbine parks have in recent years started to provide risk information for ice throw on their websites (e.g., Guleslettene vindkraftverk). Although some variation exists, the information is formatted around a warning table using colours to indicate the level of risk for certain time periods. In addition, park operators sometimes provide some text with advice on how to assess your own safety when planning to enter the park, or when you are inside the wind park (e.g., Fosen vind). An example is the advice to keep a **safe distance** of a few hundred metres (depending on the actual location) from a wind turbine.

Interviewees mentioned a number of issues around the **actual use and purpose** of the online warning information. In the interviews, we learned that the warnings on these websites are made primarily for the public / external visitors to the wind parks. A

challenge expressed by several interviewees concerned how park operators could better use the website as a channel to inform potential visitors of a wind turbine park.

> *"It would be easier for us if there were some clear guidelines on how to communicate."*
> *(Wind power researcher)*

Little is known about how often the website is accessed, by who, or how the information is interpreted. However, besides physical signs, websites are the only solution currently used to communicate the risk of ice throw in wind parks. We did, however, learn that the maintenance personnel occasionally view the warnings as a supplement to the technical procedures they always use along with their own observations. They said that they could be interested in a push service when the warning level changed. **A combination of information (warnings, advices/procedures) and skills (own observations) is seen as a good way to handle the ice throw risk for all user types.**

Throughout the interviews we discussed various aspects of the warning website content. An important topic was the **warning colours.** One interviewee said that people are used to traffic lights, so it should be okay for them to use the warning colours. There was still a question of where to set the boundaries between the different colours. Also, potential confusion could exist about what the colours actually represent. For example, the colours are based on calculation of the localized individual risk (LIRA); that is, how often an injury can happen, not how often ice throw happens. The colour thresholds were also mentioned as a factor that interviewees see a need for to better understand how thresholds are interpreted. For example, according to one interviewee, because of model uncertainty green colour does not mean no risk, but very low risk, and people should still make their own on-site assessments. However, another interviewee said that "in some situations you know that there is no risk of ice throw" (maintenance personnel). Hence, it could be considered to combine the on-site experiences and the modelling such that green actually means no risk.

Whereas yellow or orange colour rarely were mentioned, the red colour appears to stand out as something special for the interviewees. The maintenance personnel using the website reported that they had a stronger focus on their procedures and their own skills / observations when there is a red warning colour. The municipality representative said they would probably feel a responsibility for people's safety and recommend them to be careful or to not enter the park if the warning colour was red.

Another factor that was discussed is the **behavioural advice** that is provided on the website. While operators are having a general idea when and where people visit the park,

there is no insight in how people use and act upon the warning information and if visitors (are able to) comply with the advice. For example, according to one interviewee, it is probably difficult for people to assess a distance of 200 meters. Thus, it would be valuable to learn more about how the different advices are understood and used by potential visitors.

A final topic discussed in the interviews was the **reliability of the warnings**. According to one interviewee, the accuracy of the warnings is not known at the moment. This might be an important area to acquire knowledge about, since the accuracy and reliability of the information is important for use and uptake of the warnings. Interviews with maintenance personnel showed that there have been experiences with inaccurate (wrong) warnings. Importantly, if there are warnings too often, and nothing happens, they will stop using/trusting the warnings because of a "cry wolf" effect.

> *"It is important with good forecasts...if there is a warning every day, and it is not reliable, in the end it is just spam."*
> *(Maintenance personnel)*

To this add that the warnings on most of the websites do not (at the time of the study) include risk of ice or snow falling from the turbine roof, only ice thrown from the turbine blades. Ice falling from the roof is seen as a danger by several interviewees, perhaps even more important (and frequent) than ice thrown from the blades and is perceived as important to forecast and warn about. Moreover, it appears to be important to have clear communication about what is forecasted in the warnings; e.g., what does it mean for the warning communication that ice from roofs is not part of the warnings?

The interviews with experts have been helpful with providing in-depth information about some of the key concerns around the warning communication. However, the qualitative data is too limited (few persons interviewed) to be able to draw strong conclusions, and arguably not all topics (or perspectives) have been discussed. As mentioned earlier, we experienced a number of constraints in our aim to gather a broader range of qualitative insights. However, we learned from the interviews that we had to change the strategy in the work package. Rather than focusing on wind turbine park personnel (who appear to be well aware of ice-throw/fall risk, and have routine procedures for systematic risk mitigation), we shifted the focus to (potential) leisure visitors. Similarly, the lessons learned from the interviews facilitated the development of the quantitative survey (below), particularly in scoping the survey toward the relevant topics that were of concern to both the wind park operators and the local authorities. Thus, the multi-method approach taken is strongly connecting the qualitative and quantitative findings.

2.1.5 Summary of qualitative findings

- Maintenance personnel tend to have formal procedures which they follow to handle and mitigate the risk for injury and damage from ice throw/fall. Into these procedures, the personnel have built a set of specific experience/skills that appear to be highly useful to assess actual conditions when they plan to approach a turbine in the winter season;
- There appear to be very few leisure visitors to the wind parks in the winter season. Importantly, if they are not frequently visiting the park, it is not likely that they have specialized knowledge/experience assessing the risk of ice throw;
- Around wind turbine parks, there are no fences and people are free to enter the parks. However, there appears to exist different perceptions on how accessible the wind parks actually are for external use;
- Some of the wind parks use a common format for communicating the risk of ice throw. Little is known about how often the website is accessed, by who, or how the information is interpreted;
- It is essential to learn more about how the different behavioural advices is understood and used by potential visitors;
- Warning colours are a key factor for online risk communication, but its use needs to be fine-tuned so as to optimally benefit from their communicative power.
- The accuracy and reliability of the information is important for use and uptake of the warnings, also in the long-term (trust);
- A combination of information (warnings, advices/procedures) and skills (own observations) is seen as a good way to handle the ice throw risk for all user types.

2.2 User survey: Forecast information perceptions & response

Next to the series of interviews with experts, which were aimed at getting a generic overview of current routines and challenges around ice-throw/fall risk communication practices, the quantitative survey has been established as a resource for gaining insights about the perceived value of different communication tools and formats for ice-throw and ice-risk in Norwegian wind parks among the Norwegian public (see also the Methods section above).

Table 1. Respondents per region

	Frequency	Percent
Not nearby wind turbine parks		
Viken (Østfold, Akershus, Buskerud)	209	15.2
Oslo	126	9.2
Nordland	101	7.3
Vestfold og Telemark	72	5.2
Innlandet (Hedmark, Oppland)	63	4.6
Troms og Finnmark	47	3.4
Agder (Aust-Agder, Vest-Agder)	46	3.3
Nearby wind turbine parks		
Rogaland	252	18.3
Trøndelag	235	17.1
Vestland (Hordaland, Sogn og Fjordane)	134	9.7
Møre og Romsdal	92	6.7
Total	1377	100.0

A total of 1377 respondents (48% women, 52% men) participated in the survey. Average age of female participants was 44 years old, whereas the average age of male participants was 47 years old. The sample is representative on the province (fylke) level for age and gender. The province of residence was used as a **proxy to discern between people living relatively nearby wind turbine parks, and those living relatively far away from wind turbine parks** (Table 1). This distinction was based on data from NVE on distribution of wind parks in Norway. Some of the results presented below are divided into these two categories, when found relevant. Other demographic characteristics, including age groups, education level and political preference are found in Appendix A.

The results presented below cover four themes, presented across four subsections. First, the general interest in and familiarity with wind turbine parks in Norway is assessed (2.2.1). Second, we provide insights into the extent to which Norwegian residents are concerned with weather-related risks and protective measures, such as gathering information about potential weather hazards in general (2.2.2). We then turn to the context of ice-throw/fall risk in more detail. In the third section (2.2.3) we provide findings about how ice-throw/fall risk is perceived, relative to similar hazards. This section also contains detailed preferences for information seeking to know current and possible future ice-throw/fall conditions in wind turbine parks. The fourth subsection (2.2.4) engages more in-depth with a range of ice-throw warning scenarios, including warning information in CAP format. We discuss how respondents perceive and act upon different warning levels, and information formats.

2.2.1 Interest in and familiarity with wind turbine parks

A first theme addressed in the survey was about people's interest in and familiarity with wind turbine parks in Norway. Several questions were asked to get insight into the extent to which people are latently exposed to risk related to ice-throw/fall. The questions put the experiences and perceptions of people central. The results are differentiating between respondents living nearby/not nearby wind turbine parks (cf. fylke of residence as an objective proxy for exposure/proximity to wind turbines).

How near or far do people think they live from a wind turbine park in Norway?
We wanted to know if people who are categorized as living nearby/not nearby wind turbine parks also perceive this relative distance as such. Therefore, two questions targeted the subjective proximity of wind turbine parks. First, people were asked to estimate how far they live from a wind turbine park (Table 2). In both the *Nearby* and *Not nearby* group, almost half (approximately 45%) of the respondents said to live at least 20 kilometres away from a wind turbine park. However, the percentage of respondents living closer than 20 kilometres away from a wind turbine park was twice as high in the provinces that were categorized in the *Nearby* group, compared to those provinces categorized in the *Not nearby* group. **So, people's proximity to wind turbine parks is unevenly distributed across Norway, and the response indicates that people are perceiving it as such.**

Visiting a wind turbine park in Norway?
We were also interested in how familiar people are with wind turbine parks. More specifically, we wanted to get insight into how people's proximity to wind turbine parks in Norway relates to them visiting a park. This was measured by asking about people's past and future visitation. When asked if respondents had ever visited a wind turbine park

in the past, the response indicates that a minority has done so (Table 3). However, of those living relatively nearby a wind turbine park (Nearby group), more than 25 percent have visited a wind turbine park, which is more than twice the amount reported in the group that lives relatively away from wind turbine parks (Not nearby group). **Thus, living nearby a wind turbine park seems to be positively associated with visiting a wind turbine park.**

Table 2. Estimated distance of nearest wind turbine park from location of residence

		Frequency	Percent
Nearby	0-5 kilometre	49	6.9
	5-20 kilometre	171	24.0
	20-50 kilometre	156	21.9
	More than 50 kilometres	171	24.0
	I do not know	166	23.3
	Total	713	100.0
Not nearby	0-5 kilometre	22	3.3
	5-20 kilometre	73	11.0
	20-50 kilometre	79	11.9
	More than 50 kilometres	211	31.8
	I do not know	279	42.0
	Total	664	100.0

When asking about future intentions to visit, we framed the question along four different weather conditions. This gives an additional layer to the findings that shows how potential wind turbine park visits may interfere with conditions of high risk for ice-throw/fall. The results show that regardless of the distance between where people live and the nearest wind turbine park, there is a low level of interest in visiting a wind turbine park across all four weather conditions. Intentions to visit a wind turbine park however appear to become higher under sunny weather conditions, both with ‘summer’ temperatures as with temperatures below zero - the latter being a potentially favourable weather pattern for icing (Table 4). **This last finding shows that there is a likelihood that people may want to enter wind turbine parks, also while conditions for ice-throw/fall are favourable.**

Table 3. Visited wind turbine park

		Frequency	Percent
Nearby	Yes	186	26.1
	No	506	71.0
	I do not know	21	2.9
	Total	713	100.0
Not nearby	Yes	83	12.5
	No	550	82.8
	I do not know	31	4.7
	Total	664	100.0

Table 4. Likelihood to visit wind turbine park under different weather conditions

Consider that you want to visit a wind turbine park in Norway for recreational purposes, how likely would you do that in the following weather conditions?

		A sunny summer day, temperature 20 degrees Celsius		*A foggy autumn day, temperature 5 degrees Celsius*		*A foggy winter day, temperature just below 0 degrees Celsius*		*A sunny winter day after several days with snow, temperature just below 0 degree Celsius*	
		Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Nearby	Extremely unlikely	174	24.4	232	32.5	320	44.9	231	32.4
	Very unlikely	85	11.9	192	26.9	184	25.8	143	20.1
	Neither (un)likely	142	19.9	133	18.7	84	11.8	138	19.4
	Very likely	178	25.0	83	11.6	54	7.6	114	16.0
	Extremely likely	86	12.1	35	4.9	35	4.9	46	6.5
	Do not know	48	6.7	38	5.3	36	5.0	41	5.8
	Total	713	100.0	713	100.0	713	100.0	713	100.0
Not nearby	Extremely unlikely	168	25.3	239	36.0	302	45.5	237	35.7
	Very unlikely	96	14.5	163	24.5	149	22.4	123	18.5
	Neither (un)likely	140	21.1	116	17.5	88	13.3	130	19.6
	Very likely	116	17.5	56	8.4	43	6.5	80	12.0
	Extremely likely	70	10.5	29	4.4	28	4.2	38	5.7
	Do not know	74	11.1	61	9.2	54	8.1	56	8.4
	Total	664	100.0	664	100.0	664	100.0	664	100.0

Summary

- People's proximity to wind turbine parks is unevenly distributed across Norway, and the response indicates that people are perceiving it as such;
- A small group of people tends to visit wind turbine parks in Norway every now and then. Living nearby a wind turbine park seems to be positively associated with visiting a wind turbine park;
- It is likely that wind turbine parks may be visited in some weather conditions that are favourable for ice-throw/fall;
- These findings indicate that in the Norwegian context, even though the number of visits may be limited, there is a need for providing information/warnings abouts possible ice-throw/fall conditions for those who plan to visit wind turbine parks.

2.2.2 Weather-related risk information seeking and risk perception

In this section we provide insights about how people inform themselves about potential weather-related hazards in general, and how they perceive weather-related risks. These insights help to put in context people's perceptions and information preferences regarding potential risk for ice-throw/fall (addressed in detail in the following sections).

Do people seek weather-related risk information?

A first set of questions was aimed at the ways people engage with weather information and their concern with potential weather-related hazards. When asking how often people seek weather information in general, it appears that most respondents (two out of three) consult the weather forecast at least once a day, while only one out of ten respondents check the weather forecast once a week or less (Table 5). **Thus, consulting the weather forecast is a popular daily activity.**

Table 5. How often do you tend to check the weather forecast?

	Frequency	Percent
More than once per day	442	32.1
Once per day	448	32.5
More than once per week	324	23.5
Once a week	93	6.8
Seldomly	47	3.4
Never	9	0.7
I do not know	14	1.0
Total	1377	100.0

A second question asked specifically about if and how people tend to inform themselves about potentially hazardous weather conditions, in the case they plan to engage in outdoor activities (Table 6). While respondents were mostly positive about searching for information in general that helps to be prepared, this was primarily through checking for any potential weather warnings (more than 80% (very) likely). On the contrary, **only one out of three respondents stated to consult local experts about potential weather hazards**. This indicates that people may be more likely to consult a website than getting in touch with, in the context of wind turbine parks, maintenance staff that are present in the area.

Table 6. Intention to inform oneself about potentially hazardous weather

In order to protect yourself against harm from weather hazards during outdoor activities, how likely would you…	*Search for information that helps you to be prepared*		*Look for information about what you could do to protect yourself*		*Ask local experts about potential weather hazards in an area you plan to be in*		*Check if there are any weather warnings for the area you plan to be in*	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Extremely unlikely	53	3.8	60	4.4	164	11.9	41	3.0
Very unlikely	94	6.8	128	9.3	288	20.9	49	3.6
Neither (un)likely	178	12.9	324	23.5	392	28.5	139	10.1
Very likely	552	40.1	548	39.8	346	25.1	539	39.1
Extremely likely	464	33.7	281	20.4	143	10.4	579	42.0
Do not know	35	2.5	35	2.5	43	3.1	29	2.1
Total	1376	100.0	1376	100.0	1376	100.0	1376	100.0

How do people perceive weather-related risks?

Respondents were asked about how concerned they are with weather-related risks in general. This was measured with two questions, one to measure personal interest and a second to measure perceived importance (Table 7). Findings show that people are moderately interested in weather-related risks (about 50% is very to extremely interested). Moreover, a majority of respondents (about 70%) think that it is important to be familiar with weather-related risks. **This shows that on average there is a considerable interest in weather risks in Norwegian society.**

Table 7. Being concerned with weather risks

	In general, are you interested in the potential risks that certain weather conditions may bring?		*In general, do you think it is important to be familiar with the risks that certain weather conditions can pose?*	
	Frequency	Percent	Frequency	Percent
Not at all	38	2.8	24	1.7
Slightly	168	12.2	54	3.9
Moderately	443	32.2	308	22.4
Very	435	31.6	485	35.2
Extremely	257	18.7	476	34.6
I do not know	36	2.6	30	2.2
Total	1377	100.0	1377	100.0

Risk perceptions are reflected in how people feel about a specific risk, which shows that risks have a strong affective component. We measured people's affective risk perceptions for four different weather-induced events that can result in harm or damage (Table 8).

Table 8. Affective risk perceptions for ice-throw/fall and other weather-induced hazards

When going out for a hike in winter, how do you tend to feel about the possibility of these events happening to you? (Mean scores on 1-5 scale, with 1 positive affect and 5 negative affect)

	Worry	Fear	Anxiety	Dread	Affective risk (composite score)
Getting hit by ice or snow falling from roof of a house, antennas or powerlines	2.73	2.75	2.73	2.93	2.78
Getting hit by an avalanche (snow or rock)	2.78	2.87	2.86	3.04	2.89
Getting hit by a roof tile or tree branch during a storm	2.87	2.86	2.83	3.01	2.89
Getting hit by snow or ice falling from a wind turbine	**2.53**	**2.67**	**2.72**	**2.94**	**2.72**

This included people's affective response to the potential risk of ice throw/fall, relative to similar risks from weather-induced hazards. A set of four questions was used in a semantic differential format (a scale that has opposite adjectives at either end, e.g.,

confident-dreadful), for four different weather-induced hazards. A composite affective risk variable was calculated for each hazard, allowing for a comparison of average affective risk perceptions. The average scores show that overall, people tend to be just on the positive side of each affect scale, meaning that they do not associate these risks with strong negative feelings. **Moreover, it appears that the context of ice throw/fall is related with the lowest negative affect, compared to other hazards.** This means that respondents appear to be at least not more concerned about ice or snow being thrown from wind turbines than about, for example, getting hit by an avalanche.

Summary

- Consulting the weather forecast on a daily basis is done by many;
- Potential weather-related risks are of interest to most people, and people feel they need to be aware of such risks;
- People appear to not have very strong negative feelings related to possible impacts of weather-induced hazardous events;
- People are similar or even less concerned about the risk of getting hit by snow or ice from a wind turbine, when compared to other typical weather-induced hazards;
- When planning outdoor activities, the majority of people consults the weather forecast and other information to get informed about weather-related risks;
- People are more likely to consult impersonal sources (websites) than local experts. This may have implications for the potential role of maintenance personnel in the risk communication.

2.2.3 Information seeking in the ice throw/fall context

The previous section covered general assessments of how people perceive weather-related hazards, and how they tend to inform themselves about potential risks emerging from hazardous weather conditions. In this section and in the following section, we turn to the specific context of ice throw/fall in wind turbine parks. Here we address information preferences and perceived ability to gather information that could help mitigate risk for injury when entering a wind turbine park.

Which information sources about ice-throw/fall risks do people prefer to use?
In order to improve the communication of potential risk of ice throw/fall to potential users of areas where wind turbines are located, we investigated the perceived suitability of various information channels and sources for communicating warning information. First, respondents were asked to rate a list of risk communication channels, including those typically used in the wind turbine context (e.g., physical signs), more generic warning

channels used in the weather context (e.g., Yr.no) and typical channels for local communication (e.g., websites for outdoor activities) (Figure 5). **It appeared that Yr.no was the most preferred of all the suggested channels.** Yr.no is the channel (website/app) of the Norwegian Meteorological Institute and the Norwegian Broadcasting Corporation to communicate the daily weather forecasts. Yet, while Yr.no does provide weather warnings, these do not currently include specific warnings for ice throw/fall risk. Next, **physical warning signage was seen as a suitable form of communication** as well. Websites with information about a specific wind turbine park were also among the more preferred sources. On the other hand, websites related to local leisure activities (DNT, recreation organisations) were seen as less appropriate channels. Overall, it seems that **people prefer the information channels that are familiar** to them, when it comes to receiving ice throw/fall risk information.

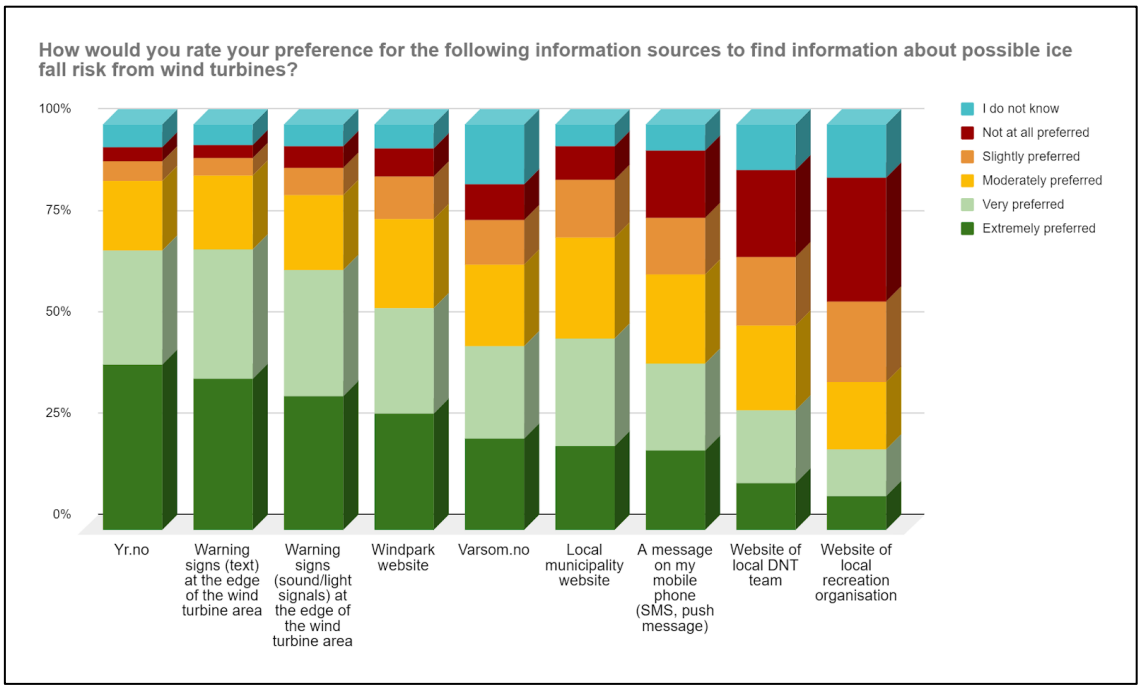

Figure 5. Information preferences

Do people know how to assess possible ice throw/fall risks?

In the professional context of maintenance of wind turbine parks, various risk management routines are in place. These include a range of perceptual assessments, where individuals (cf. maintenance staff) attempt to establish a certain level of situational awareness about the potential for ice throw/fall. Collecting various visual cues complements the assessment of other types of information (e.g., warnings, forecast model output). We explored the extent to which people feel themselves capable of performing

such forms of 'expert' information seeking (Figure 6). A general assessment of current weather conditions (including forecasts) appeared to be seen as relatively easy. However, the **typical ways of collecting cues when inside an area with wind turbines tend to be seen as difficult for most respondents.** For example, estimating distance between oneself and a wind turbine appears to be difficult (this is a challenge that is well known from other contexts, e.g., hunting). See also Section 2.2.4 for perceived preferences across warning scenario contexts.

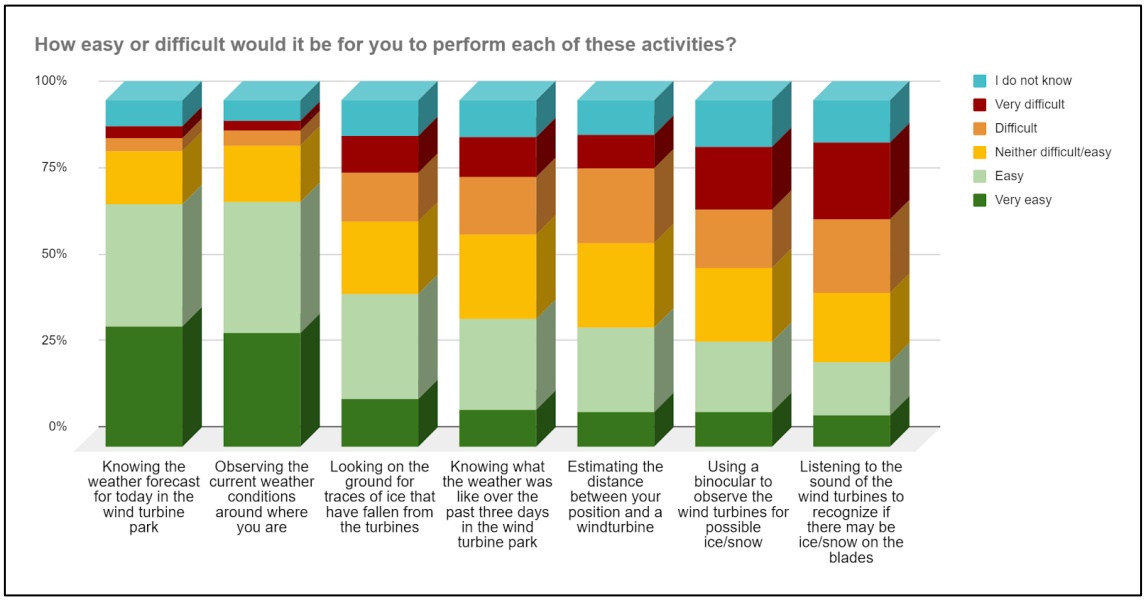

Figure 6. Perceived ability to assess ice throw/fall conditions

Summary

- Information channels for weather-related warnings that people are familiar with, seem also to be preferred for receiving ice throw/fall risk information;
- Physical signs are highly preferred as a source for ice throw/fall risk information.
- Yr.no is the most preferred source for ice throw/fall risk information, even though it currently does not provide such information;
- Gathering weather information (forecast, observe conditions) are seen as a relatively easy measure to assess risk for ice throw/fall;
- However, typical additional assessments (cue observations) used by experts appear to be seen as difficult to perform.

2.2.4 Ice risk warning scenarios: perceptions and response

Ensuring accurate and timely communication of ice throw/fall risk in a format (e.g., warnings) that is understood by those who need it is essential, whether it is a first-time or a well-seasoned visitor of wind turbine parks. The limited 'real-life' exposure of people to wind turbine areas, and to the risk of ice throw/fall in particular, makes it difficult to investigate actual risk information behaviour and experience-based perceptions. Yet, the survey provided an opportunity to explore people's responses to warning information by exposing respondents to several scenarios around an ice throw/fall risk warning situation.

The warning scenarios were aimed to explore how different levels (Yellow, Orange, Red) of CAP-based warning information formats are perceived and acted upon. The warning format was inspired by CAP warnings that are currently used both in Norway (Yr.no, Varsom) and elsewhere, and tailored to the ice throw/fall context (see Figure 7 and 8).

Please carefully read the following information, before continuing with the survey.
Consider the following scenario:

Activity
It is a Saturday morning in February. You plan to go for a hike or ski tour, starting at 09.30h until 14.30h. The distance of the trip is within your physical ability.

Weather information
After a week of variable weather, with snow showers and temperatures just below freezing, the forecast for both Saturday and Sunday is sunny with some clouds, wind northwest 5m/s and a maximum temperature of -1 degrees Celsius. There is snow on the ground, but it is easily possible to both walk and ski.

Route information
The route of your trip will go through an area where various wind turbines are located. The following information about the wind park is available to you:

Figure 7. Scenario description.

Respondents were randomly assigned to one of four different warning scenarios A, B, C or D. Each scenario included the same activity context, in which respondents had to imagine that they planned a hike/ski tour during the winter season in an area with wind turbines (see Figure 8). Next to a brief text explaining the activity, respondents were presented with the CAP-based warning: group A and B were presented with a yellow level warning, while group C and D were presented with a red level warning. In addition, half of the participants received background information with general information and tips about behavioural skills to stay safe from harm of possible ice throw/fall. This

additional information (called ‘Vindpark vett’ in Norwegian, which translates to ‘wind knowledge/sense’) was presented to group B and D.

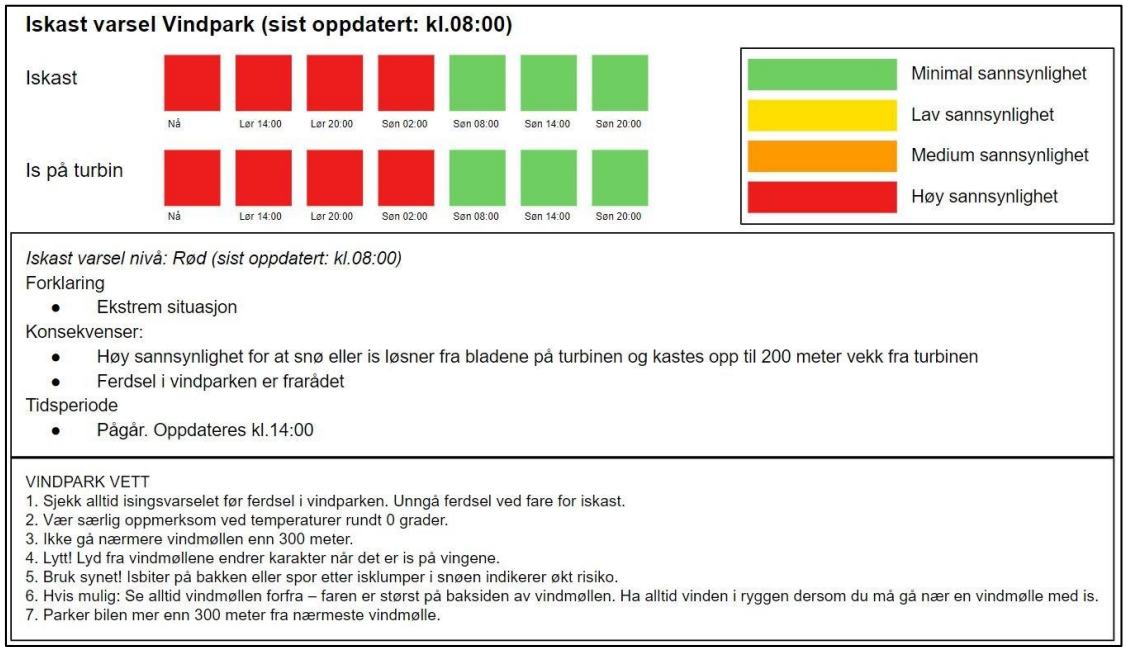

Figure 8. Example of warning information (Scenario D)

After being presented with the warning scenario, respondents answered a set of questions about their understanding of the warning information, what decisions they would make regarding their plans for a trip through the wind turbine park, and what distance from a wind turbine they would feel safe, given the forecasted ice throw/fall risk.

Do people find the warning information understandable?

A key factor in successful risk communication is ensuring that the warning message is conveyed and understood. We measured this with a set of five statements that cover different indicators of understanding. In Figure 9 the average response score for each statement is provided, contingent on the four warning scenarios. The average scores reflect responses on a 1-5 scale (totally disagree-totally agree), meaning that higher scores indicate a positive response and thus a higher degree of understanding of the warning information.

The results show that the warning information is overall positively assessed. On average, **respondents agree that the information is easy to understand and credible.** The warning information is also perceived to have an impact in terms of the extent to which it makes people concerned about their safety. This is, perhaps unsurprisingly, more the case in the red scenario than in the yellow scenario. Related to safety concerns, respondents on average agree that the information gives them 'actionable' information that helps them accommodate their behaviour so that they stay safe. Thus, the overall high scores on aspects of warning understanding across the four scenarios show that **warning information on ice throw/fall is appreciated as a qualitative measure to mitigate risk on the individual level.**

Several (small, but statistically significant) differences in the responses across the scenarios indicate that variations in content may have an impact on the level of understanding. This seems to be mostly affected by the warning levels, and less by the additional information provided in the skills information flyer (Vindvett). This may indicate that a **higher risk level (for example reflected by the colour red) triggers people's attention to information and to process the information more actively** into an assessment of possible consequences and mitigating behaviour. Similar effects have been found in other research studies (Association for Psychological Science, 2011).

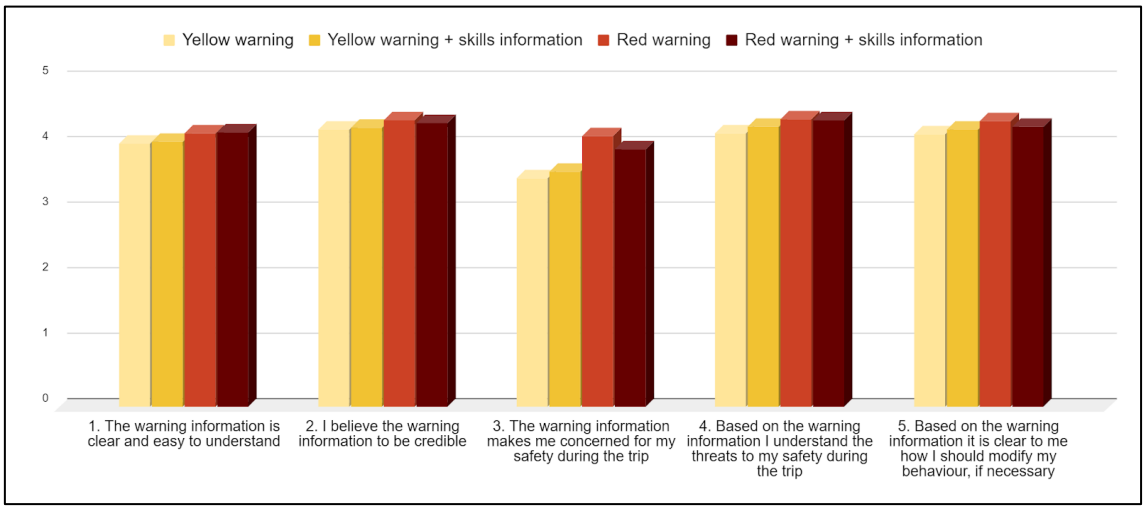

Figure 9. Average agreement with statements about warning information understanding, per warning scenario (Statements were assessed on a 1-5 scale (1 totally disagree, 5 totally agree))

What do people decide, based on the warning information?

A next set of questions measured the degree to which people intend to 'act upon' the warning information that was presented to them (Figure 10). Two options (1 and 6) represented the two extreme responses: cancellation and business as usual, respectively. **To cancel the trip was especially an option under the red warning scenario.** To go on as planned without obtaining any further information appeared a relatively unlikely response under all conditions, but especially in the red scenario without extra information about behavioural skills (statistically significant). Questions 2-5 referred to various types of information seeking. To seek additional information about weather conditions before entering the park was likely under all scenarios (Q2).

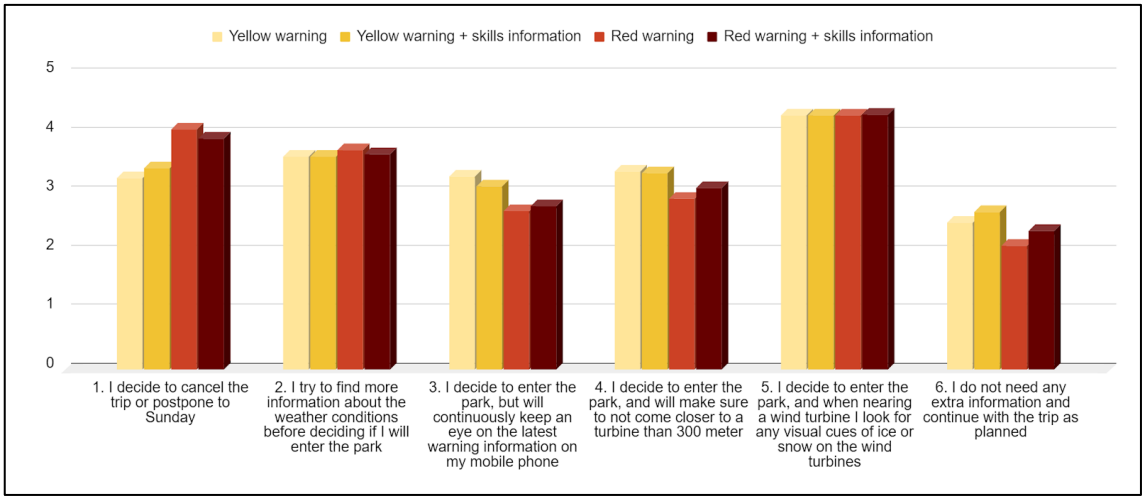

Figure 10. Average perceived likelihood of protective actions, per warning scenario (Statements were assessed on a 1-5 scale (1 very unlikely, 5 very likely)).

Interestingly, to enter the park under the different warning levels while gathering further information, or ensuring to keep a safe distance appeared more likely under the yellow scenario (Q3, Q4, statistically significant). The relatively lower scores under the red scenario may be interpreted as people being generally hesitant to enter the wind turbine park in the first place (cf. the high likelihood of cancelling the trip under a red warning). Overall, these findings can be interpreted as a sign that **any warning for ice throw/fall should be accompanied by timely and up-to-date weather information** which people will guide in adapting plans if needed.

In all scenarios it was seen as a likely option to enter the park and look out for ice/snow on the wind turbines (Q5). Making their own observations as the most popular means to assess actual icing conditions implies a need for people to have skills to find and interpret cues. Obtaining such cues from the environment (observing snow/ice, listening to sound of turbines) however was seen as relatively difficult (see Section 2.2.3), meaning that **educating about how to develop cue observation skills may be a key challenge to address in future risk management plans.**

At which minimum distance do people feel safe?

An obvious but important way of staying safe from harm caused by ice or snow thrown from wind turbines is to stay well outside of the space in which ice/snow may hit the ground. Providing information about safety distance is also considered to be a sensible way to frame the spatial dimensions of ice throw/fall risks. Therefore, an additional question focused on the way people would feel about what a safe distance from wind turbines is, under different warning levels. In most currently operational warning formats, a threshold distance of 300 meters around a wind turbine is used. This distance was also used in this study.

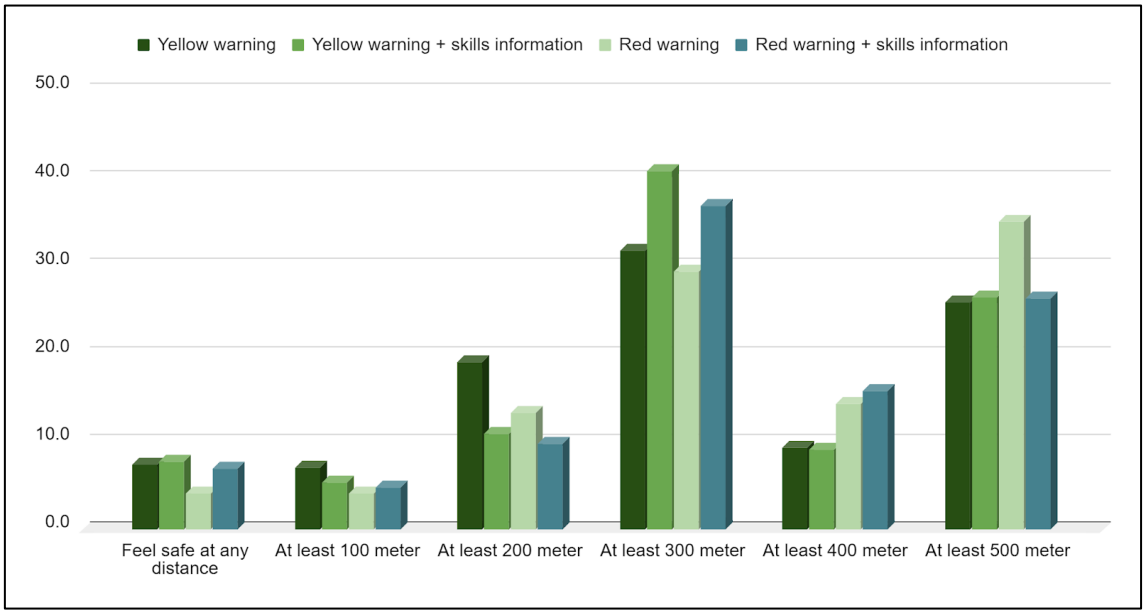

Figure 11. Perceived minimum safety distance for different warning scenarios (percentages).

Figure 11 shows people's perceived minimum distance from a wind turbine. **A minimum distance of at least 300 meters appears to be the most preferred.** Most likely this shows that people have taken notice of the distance recommendations provided in the warning information. Especially respondents in the red warning scenario without additional skill information show a preference for keeping larger distances between

themselves and a wind turbine (significant difference), compared with respondents in the other three scenarios. In addition, there is a clear preference for staying at least 500 meters away from a wind turbine (Figure 11). This can be interpreted as **a large group of respondents having a preference to stay as far away from a wind turbine as possible, regardless of the actual risk for ice throw/fall.**

What parts of the warning information were easy/difficult to understand?
After having answered all questions related to the warning scenario, respondents were asked to evaluate the warning information. Two open questions allowed respondents to give feedback on the extent to which different parts of the warning information were easy or difficult to understand, respectively.

The responses were categorized into common themes. Positive feedback (parts of information that was found understandable/useful) is shown in Figure 12. Next to a large number of respondents who stated that all warning information was understandable ('Everything', Warning general'), more detailed answers gave a richer idea of which parts of the warnings were appreciated. The **warning colours were seen as useful by many**, **particularly when combined with specific details presented in the text (timing, severity).** The information about **behavioural advice / possible consequences** was also picked up on, especially under the red warning level. Related to behavioural advice, it is interesting to note that the information about safety distance was mentioned as useful.

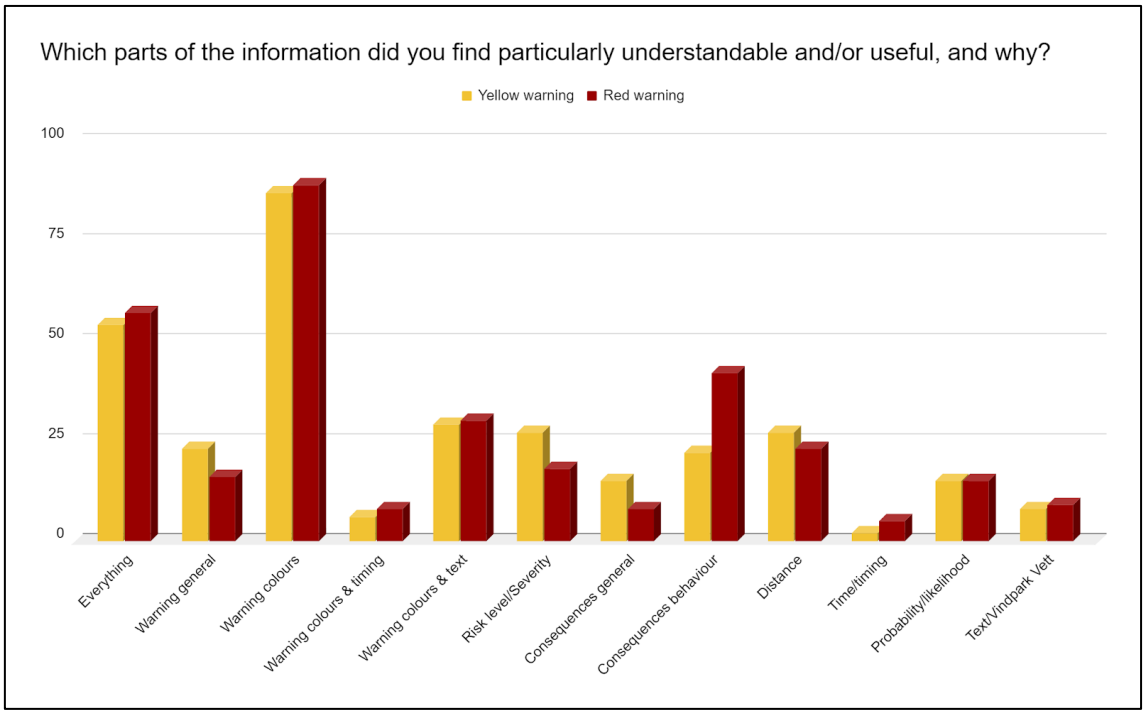

Figure 12. Warning information aspects that were evaluated as understandable/useful.

Figure 13 shows the parts of the warning information that were difficult to understand, as mentioned by respondents. An important signal is the **relatively high number of people who feel that there is too much information in the warning**, which is challenging them to digest the key message. Other aspects mentioned include the warning colours, the distance indications and **aspects related to the timing/duration of the risk levels.** For example, it was mentioned that the different time slots (6 hours) took some effort to understand. For the yellow warning level, it is interesting to note that there were relatively many respondents who found the warning colour difficult to interpret. Possibly related to this is the relatively high number of respondents under the yellow scenario who found the warnings to include contradictory information. Thus, a yellow warning level can be interpreted as ambiguous, and makes people wonder if it is safe or not to enter the wind turbine park. Overall, these findings suggest that the **CAP format for ice throw/fall warnings is suitable** for communicating the risk related to ice throw/fall. However, **fine-tuning the combination of colours and guiding text requires systematic testing**, in order to arrive at an optimal format.

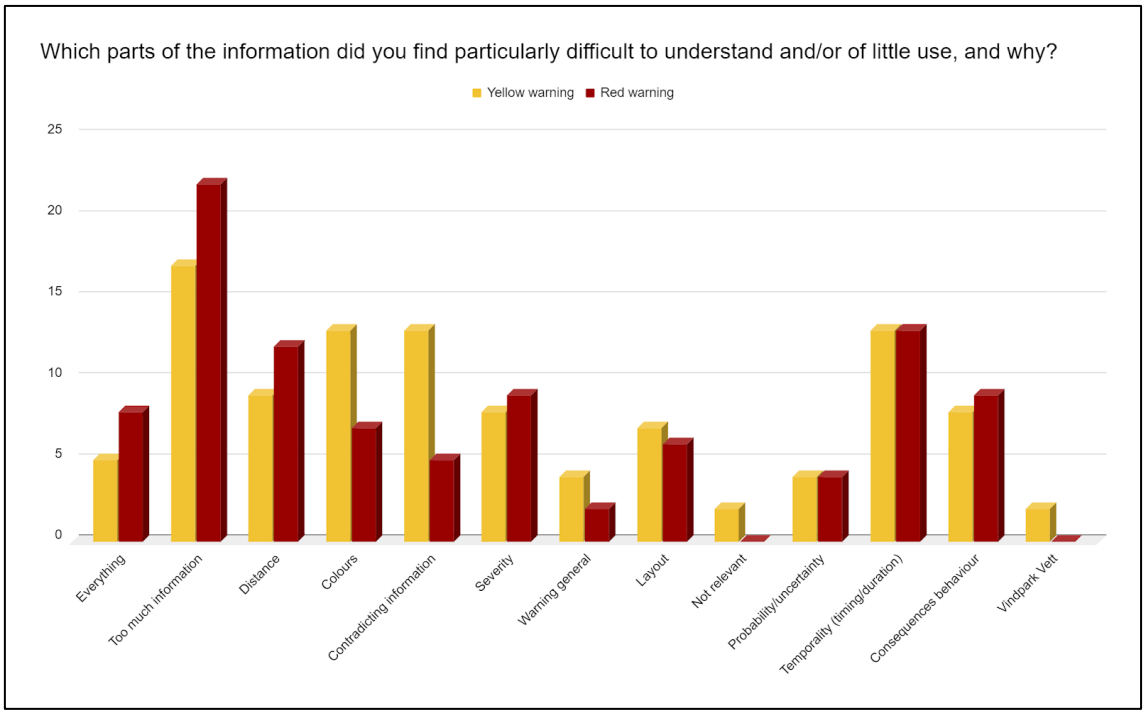

Figure 13. Warning information evaluated as difficult to understand/not useful.

Summary

- Warning information on ice throw/fall is appreciated as a qualitative measure to mitigate risk on the individual level. Warning information appears to be overall understandable and actionable;

- CAP format for ice throw/fall warnings appears to be suitable for communicating the risk related to ice throw/fall;
- Fine-tuning the combination of colours and guiding text requires systematic testing, in order to arrive at a format that is actionable, while not risking information overload;
- Warning for ice throw/fall that is accompanied by timely and up-to-date weather information may help people in adapting plans if needed;
- Representation of higher risk levels (for example reflected by the colour red) appears to trigger people's attention to information and to process the information more actively, and is perceived to have less ambiguity in terms of possible impacts and behavioural advice;
- Making own observations about actual weather/icing conditions appears a preferred risk mitigating measure. However, this preference may be at odds with the finding that people lack the skills to perform such observations;
- A minimum distance of at least 300 meters appears to be the most preferred to feel safe. However, a large group of respondents seems to prefer to stay as far away from a wind turbine as possible, regardless of the actual risk for ice throw/fall.

3 Recommendations for communication

A key objective of this report is to contribute to a systematic knowledge base that can inform the qualitative measures, as described in Paragraph 4.3.3. of the International Recommendations for Ice Fall and Ice Throw Risk Assessments (IEA Wind TCP Task 19, 2018). Such qualitative measures, including adequate risk communication formats, are needed to mitigate risk from ice-throw and ice-fall, but "cannot be assessed quantitatively, [and] should be considered independent from the measures discussed [in other sections of the report]" (p.26).

The aim of this report is thus to address some key challenges in the current ways ice-throw/fall hazards are communicated about and how this communication can be improved in Norwegian wind turbine parks, especially when aiming to inform (potential) non-expert users. The research and findings presented in this report have been guided specifically by the following questions:

1. *How can the application of online information channels for ice-throw/fall risk be improved, as to optimally communicate risk information (CAP warnings, impacts, behavioural advice), facilitate wind park operators in their communication with potential visitors to the park and give 'actionable' risk information to users?*

2. *Which measures can enhance the communication of primary risk information (CAP warnings, impacts, behavioural advice), such that it helps people to build skills and awareness needed to minimize risk of injury when entering Norwegian wind turbine parks?*

The findings presented in this report indicate that in the Norwegian context, even though the number of visits may be limited, there is a need for providing information/warnings abouts possible ice-throw/fall conditions for those who plan to visit wind turbine parks. Bredesen et al. (2017) already give some clear pointers in terms of the requirements for adequate risk communication. However, there are many factors to consider when aiming to convey potential risks, and warning communication formats should be tested empirically on their impact. The Office of Coastal Management at the National Oceanic and Atmospheric Administration (NOAA), provides seven best practices for risk communication that can be of interest also to the ice risk context (NOAA, 2016). They state that the ultimate goal of risk communication is to get someone to take an action to reduce their risk from hazards. Risk awareness is a key outcome of successful risk

communication, but insufficient when not knowing what actions to take. Hence, the communication should include information about recommended actions:

- The first advice by NOAA (2016) is to have an informed plan with your communication. You should know what you want to achieve - e.g., a change in behaviour - and how you will achieve it. What you say, how you say it and how you deliver it are all important;
- Secondly, you should speak to your audience's interests, not yours. Connecting with your audience's values and concerns will help you establish a relationship. You should be honest about what you (don't) know;
- The third advice is to explain the risk. You could use stories and visuals to make it personal and help your audience understand the impacts and the hazards;
- A fourth piece of advice is to offer options for reducing risk. Knowing how to respond to risk can be confusing. Hence, if you show some options / guidance, that might help your audience;
- The fifth advice is to work with trusted sources. People often seek confirmation from multiple trusted sources to help them make decisions on what actions to take.
- Sixth, test your message or your product on target audience members, and get feedback - and be willing to make changes;
- Finally, you are advised to use multiple ways to communicate, as many people like to receive information in different ways.

When transferred this information to ice-risk communication context, the colours used in the warnings are important, because they will most likely influence people's decisions about visiting the wind park or not. For example, red colour indicates "stop" to many people, whereas green colour is by many seen as a go-ahead signal. The colours in between are more ambiguous. Compared to traffic lights, most people accept green as a signal to drive and red as a signal to stop, and do this automatically. If the traffic light is yellow/orange, then the driver needs to invest cognitive effort more in the decision whether to stop or to drive, and the outcome depends on a range of factors. Since the context of visiting a wind park will be a new experience to many people, they need to be assisted to make informed decisions. One way to do that is for example to provide information on consequences and advice related to the different warning colours. Such information could increase value by connecting it to the audience's values and concerns, by making it personal, and by offering options to reduce risk. There is, however, no guarantee that this type of supplementary information will be read by all potential visitors to the wind parks. Therefore, continuous monitoring of the risk perceptions and behavioural patterns of wind park visitors may help getting a grip on the effectiveness of qualitative measures in ice throw/fall risk management.

The following sections give a set of recommendations, based on the combination of qualitative and quantitative responses that were outlined in the previous chapters, in combination with the broader insights from the risk communication literature. The recommendations are targeted at the use of communication channels (3.1) and the formatting of information (3.2), hereby referring to the two main research questions. In addition, recommendations are made for the future development of qualitative measures for risk management in the ice throw/fall context more generally (3.3).

3.1 Enhancing risk information accessibility (RQ1)

3.1.1 A consistent portfolio of communication channels

To effectively communicate about ice throw/fall risks, the ultimate objective should be not just to inform, but provide options for adaptive behaviour as to reduce/minimise the risks (cf. NOAA, 2016). A key factor to this end relates to the choice of communication channels. The findings reported above indicate that:

- A combination of information (warnings, advices/procedures) and skills (own observations) is seen as a good way to handle the ice throw/fall risk for all user types (2.1.4);
- At least some of the wind parks in Norway use a common format for communicating the risk of ice throw/fall (2.1.4);
- When planning outdoor activities, the majority of people consults the weather forecast and other information to get informed about weather-related risks (2.2.2);
- People are more likely to consult impersonal sources (websites) than local experts. This may have implications for the potential role of maintenance personnel in the risk communication (2.2.2);
- Information channels for weather-related warnings that people are familiar with, seem to be preferred for receiving ice throw/fall risk information (2.2.3);
- Physical signs are highly preferred as a source for ice throw/fall risk information (2.2.3).

Based on these findings the following recommendations are made:

1. **Channels used for ice throw/fall risk communication should ideally consist of a portfolio of multiple outlets, including both physical signs in/around a wind turbine park, and websites;**

2. **The channel portfolio used should be built on the premise that at least part of the channels is trusted by the intended audience, and regularly consulted by them (for example, Varsom.no);**
3. **The channel portfolio should be consistent in its messages, which allows for people to create a confirmative impression of the risk situation, and how to cope with it;**
4. **Consistency across channels also implies a recognizable format across both physical and digital channels (see also the recommendations about information formats);**
5. **The portfolio of channels should provide options for consulting both weather information and current ice throw/fall risk information at moments/places where people tend to make a behavioural decision that may affect their exposure to ice throw/fall risks. For example, physical signs at a parking area may include a website URL or a QR code that brings people directly to the latest online risk information.**

3.1.2 Accounting for different levels of risk (un)familiarity

The current degree of leisure activities in Norwegian wind turbine parks appears low, at least for the parks that we gathered information about. However, there is a considerable number of potential visitors for which risk communication should be in place, many of which are not familiar with the phenomenon of ice throw/fall. The communication channels and sources to be included in the portfolio should take into consideration the varied levels of familiarity with the specific hazard context of ice throw/fall across different user groups. Specifically, the findings indicate that:

- Maintenance personnel have formal procedures they follow to handle and mitigate the risk for injury and damage from ice throw/fall. Into these procedures, the personnel have built a set of specific experience/skills that appear to be highly useful to assess actual conditions when they plan to approach a turbine in the winter season (2.1.2);
- There appear to be very few leisure visitors to the wind parks in the winter season. Importantly, if they are not frequently visiting the park, it is not likely that they have specialized knowledge/experience assessing the risk of ice throw/fall (2.1.3; 2.2.1);
- A small group of people tends to visit wind turbine parks in Norway every now and then. Living nearby a wind turbine park seems to be positively associated with visiting a wind turbine park (2.2.1);
- Consulting weather forecasts on a daily basis is done by many (2.2.2);

- Potential weather-related risks are of interest to most people, and people feel they need to be aware of such risks (2.2.2);
- People appear to not have very strong negative feelings related to possible impacts of weather-induced hazardous events (2.2.2);
- People are similar or even less concerned about the risk of getting hit by snow or ice from a wind turbine, when compared to other typical weather-induced hazards (2.2.2);
- People are more likely to consult impersonal sources (websites) than local experts. This may have implications for the potential role of maintenance personnel in the risk communication (2.2.2);
- The literature shows that familiarity can lead to both higher and lower risk perceptions, depending on the context (Joslyn et al. 2018).

Based on these findings, the following recommendations are made:

1. **Familiarity with available risk information channels among potential user groups should be nurtured, for example by an annual awareness campaign;**
2. **Communication of unfamiliar risks may benefit from using the sources that (potential) users are able to find. Therefore, wind park operators aiming to communicate ice throw/fall risk information should connect with the (digital) channels available on the national and regional levels (including local media), next to using their own websites;**
3. **People appear relatively familiar with weather-related risk information, and many have adopted a routine around consulting weather forecasts on a daily basis. Framing the ice throw/fall as a weather hazard, as opposed to a technical hazard, may improve understanding and uptake.**

3.2 Information formats (RQ2)

Our findings show that it is likely that wind turbine parks may be visited in some weather conditions that are favourable for ice-throw/fall. Accurate and timely warnings to convey the possible risks related to icing conditions is therefore warranted. An essential factor in successful communication is the extent to which information is formatted in an understandable way.

3.2.1 CAP format as template for ice throw/fall warnings

The quantitative survey explored perceptions of ice fall/throw warnings, based on the CAP format, and show us that:

- Warning information on ice throw/fall is appreciated as a qualitative measure to mitigate risk on the individual level. Warning information appears to be overall understandable and actionable;
- CAP format for ice throw/fall warnings appears to be suitable for communicating the risk related to ice throw/fall;
- Warning colours are a key factor for online risk communication, but its use needs to be fine-tuned so as to optimally benefit from their communicative power;
- The accuracy and reliability of the information is important for use and uptake of the warnings, also on the URL long-term (trust in forecast);
- Fine-tuning the combination of colours and guiding text requires systematic testing, in order to arrive at a format that is actionable, while not risking information overload.

Based on these findings, and the current knowledge on warning communication in the literature, the following recommendations are made:

1. **Online warnings for ice throw/fall may adopt the CAP format, as to be consistent in their content across wind park contexts, and consistent with a globally supported format for warning communication;**
2. **Online warnings for ice throw/fall are recommended to put a consistently used (similar to all relevant Norwegian wind parks) warning colour scheme as a central ingredient;**
3. **Online warnings for ice throw/fall should avoid overloading their intended audiences with information that attenuates understanding and, consequently, behavioural action. It is therefore recommended to:**
    - **Layer warning information according to the model proposed by Popovic et al. (2021) (see Figure 3, section 1.2.3);**
    - **Use the warning colours as main tool to create awareness of the risk level;**
    - **Clearly explain the meaning of each colour level (risk versus probability);**
    - **Make a clear distinction between ‘no risk’ and ‘low risk’ (green level)**
    - **Use text and/or graphics to inform about impacts and advice (see 3.2.2);**

4. **Online warnings should be primarily formatted to tailor non-expert audiences, since expert users (cf. maintenance personnel) may best be catered through other channels that allow for integration into Standard Operating Procedures;**
5. **Additional information that is made available online, which is aimed at conveying insights about on-site skills to assess conditions should complement the warning information. However, to avoid information overload this information may best be presented on a separate page or in a second layer (cf. layering, see also 3.2.2).**

3.2.2 Impact information and behavioural advice

Next to the warning format based on the CAP template in general, a key aspect of warning information that helps people to mitigate risk and make decisions that keep them safe is information about possible impacts of prevailing conditions, and suggestions for behavioural adaptation. The findings indicate that:

- Warning for ice throw/fall that is accompanied by timely and up-to-date weather information may help people in adapting plans if needed;
- Representation of higher risk levels (for example reflected by the colour red) appears to trigger people's attention to information and to process the information more actively, and is perceived to have less ambiguity in terms of possible impacts and behavioural advice;
- Typical additional assessments (cue observations, distance assessments) used by experts appear to be seen as difficult to perform by the general public;
- A minimum distance of at least 300 meters appears to be the most preferred to feel safe. However, a large group of respondents seems to prefer to stay as far away from a wind turbine as possible, regardless of the actual risk for ice throw/fall.

Based on these findings, in combination with existing insights from risk communication literature, the following recommendations are made:

1. **Indications for distance to a wind turbine are to be clearly communicated and available within a wind turbine park. Next to the need to address individual skills (see 3.3), this may require innovative technological solutions (augmented reality, location-based alerts);**

2. **Any warning level (including a no risk situation) should be accompanied by clear behavioural advice for how to stay safe from harm by potential ice throw/fall;**
3. **Background information about ice throw/fall phenomenon may be included on both physical signs and online, but to avoid cluttering of information this should be clearly separated from the actual warning information (cf. layering).**

3.3 The long-term perspective: building actionable knowledge

3.3.1 Observation skills

An important challenge related to risk mitigation pertains to the potential lack among the general public of individual skills needed to observe current conditions and risk cues when approaching a wind turbine. The findings presented above indicate the following:

- Maintenance personnel have formal procedures they follow to handle and mitigate the risk for injury and damage from ice throw/fall. Into these procedures, they have built a set of specific experience/skills that appear to be highly useful to assess actual conditions when they plan to approach a turbine in the winter season;
- Typical additional assessments (cue observations) used by experts appear to be seen as difficult to perform by the general public;
- There appear to be very few leisure visitors to the wind parks in the winter season. Importantly, if they are not frequently visiting the park, it is not likely that they have specialized knowledge/experience assessing the risk of ice throw/fall;
- Gathering weather information (forecast, observe conditions) is seen as a relatively easy measure to assess risk for ice throw/fall, and making own observations about actual weather/icing conditions appears a preferred risk mitigating measure. However, this preference may be at odds with the finding that people lack the skills to perform such observations.

Thus, there seems to be **a strong need for transferring these competencies beyond the professional context and making them available to the wider scope of potential users** of wind turbine parks. The following recommendations are made to this end:

1. **Facilitate interaction with wind turbine park personnel and local actors (municipalities, leisure organisations) to co-develop an awareness programme that facilitates the development of individual skills to observe and recognize cues that signify potentially hazardous icing conditions;**

2. **Target awareness programs to specific user groups that are most likely exposed, where possible. Examples of such groups are reindeer herders or recreationists in ski areas;**
3. **A flyer has been developed with tips for safe access of wind turbine parks during winter. The objective of the flyer is to inform and create awareness (Vindvett, a sense for wind). It is recommended to consider expanding the Vindvett concept to an online webpage that provides a list of short videos, for example featuring wind turbine maintenance personnel that explains specific methods for assessing icing conditions.**

3.3.2 Monitoring perceptions and behaviours

We observe an opportunity to strengthen risk communication for Norwegian wind parks at the national level, specifically with respect to the need for building a systematic database of insights into perceived impacts, risk perceptions and protective behaviour across the variety of wind parks users. Such insights are pertinent, given the ambitions of IEA Wind TCP Task 19 for providing qualitative risk mitigation measures. Furthermore, this need is strengthened by the recent request from NVE to improve risk communication for ice throw/fall risk.

In addition, the findings in the report highlight that:

- While some of the wind parks use a common format for communicating the risk of ice throw, little is known about how often the website is accessed, by who, or how the information is interpreted;
- It is essential to learn more about how the different behavioural advices are understood and used by (potential) visitors;
- A small group of people tends to visit wind turbine parks in Norway every now and then. Living nearby a wind turbine park seems to be positively associated with visiting a wind turbine park.

Based on this, we recommend to consider the following measures:

1. **Set up a methodology for continuous monitoring of:**
   - **Impacts of changes in the risk communication practices;**
   - **Risk perceptions for ice throw/fall;**
   - **Behavioural activity in wind turbine parks, and possible change over time;**
2. **Methods and tools to be considered include:**

- **A two-yearly quantitative survey among the Norwegian public, based on the quantitative survey reported in this document;**
- **Case studies in selected wind parks, to test best practices for warning communication;**
- **A (national) expert committee on risk communication for ice throw/fall that includes representatives of key Norwegian user groups.**

3.4 Wrap up

Summarizing the findings and recommendations, we can make a distinction between two segments of receivers of information about ice throw/fall risks. On one hand, it appears that the wind park personnel (operators, contractors) are handling the ice throw/fall risk quite well already. They have developed a relevant set of individual skills, and use standardized procedures to assess and mitigate the risk for injury and damage. Given that maintenance personnel are regularly and with a specific purpose entering areas with a risk to be impacted by ice/snow, the implementation of communication tools for them should be part of the standardized operation procedures. On the other hand, there are (potential) visitors of the park, and a warning system and appropriate communication of the danger is necessary. Many of the recommendations above apply to advancing the communication and warning practices for this audience. Both in the literature, and in our qualitative and quantitative data, the consistent use of warning colours appears as a key for successful risk communication. Specifically, green (safe) and red (danger) colours stands out and should be included in the communication strategy. In addition, yellow and orange colours appear to be perceived as more ambiguous, and are more demanding to understand to the extent that an intended audience is able to act upon their meaning, and make decisions about what to do. Since it is recommended to give clear (not too general) advice to all types of users what they should *do* given a certain warning level, warning information aimed at wind farm operators may include a wider range of colours and parameters, while warning information aimed at the broader public may be more restrictive. Finally, the findings indicate that even though there is a clear distinction to be made between these to receivers of risk information, there is an imperative need to build sustainable connections between the ways ice-throw/fall risk is handled by wind park personnel and other users. The expert knowledge and skills as developed in the professional context should form a template for creating an awareness about ice throw/fall as a natural hazard among the broader scope of wind farm users.

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Appendices

A. Survey tables – Demographic characteristics

Age and Gender distribution				
		Frequency		Percent
Male 18-29		128		9.3
Female 18-29		179		13.0
Male 30-39		113		8.2
Female 30-39		134		9.7
Male 40-49		123		8.9
Female 40-49		123		8.9
Male 50-59		111		8.1
Female 50-59		107		7.8
Male 60-99		191		13.9
Female 60-99		168		12.2
Total		1377		100.0

Respondents per region				
		Frequency		Percent
Viken (Østfold, Akershus, Buskerud)		209		15.2
Oslo		126		9.2
Innlandet (Hedmark, Oppland)		63		4.6
Vestfold og Telemark		72		5.2
Agder (Aust-Agder, Vest-Agder)		46		3.3
Rogaland		252		18.3
Vestland (Hordaland, Sogn og Fjordane)		134		9.7
Møre og Romsdal		92		6.7
Trøndelag		235		17.1
Nordland		101		7.3
Troms og Finnmark		47		3.4
Total		1377		100.0

Education level		
	Frequency	Percent
Grunnskolenivå	74	5.4
Videregående skolenivå	357	25.9
Fagskolenivå	142	10.3
Universitets- og høgskolenivå, kort (t.o.m. 4 år)	468	34.0
Universitets- og høgskolenivå, lang (mer enn 4 år)	310	22.5
Ingen	26	1.9
Total	1377	100.0

Political preference		
	Frequency	Percent
Arbeiderpartiet (Ap)	255	18.5
Høyre (H)	195	14.2
Senterpartiet (Sp)	189	13.7
Fremskrittspartiet (FrP)	153	11.1
Sentralistisk Venstreparti (SV)	88	6.4
Rødt (R)	67	4.9
Miljøpartiet De Grønne (MDG)	57	4.1
Venstre (V)	55	4.0
Kristelig Folkeparti (KrF)	51	3.7
Ingen/ønsker ikke å oppgi	267	19.4
Total	1377	100.0

B. Interview/focus group guideline

Focus group guide

- ❖ Date:
- ❖ Facilitators:
- ❖ Participants:

Introduction

- Facilitators
- Research project
- Purpose of this meeting

Participant consent

- Read consent statement and get verbal consent/Send consent form and have it signed
- Recording online meeting

Start session

- Any questions?
- Start recording

#	Spørsmål	Kommentar
1	Arbeidsoppgaver ● Hvilke aktiviteter/oppgaver gjør du som påvirkes av (fare for) iskast? ○ Når har dere bruk for iskastvarsel? ○ Kun bruk for varsel på dagtid? Skiftordning?	10 min
2	Erfaring med is-kast ● Hvor ofte skjer det? ● Hvordan brukes denne erfaringen?	5 min
3	Bruk av iskastvarsel av operatører/vedlikeholdspersonell ● Hvordan ville du tenkt når du så dette varselet? ○ Er fargesystemet nyttig? (sannsynlighetene) ○ Hva betyr fargene for dere? ○ Hvor ofte bruker dere varslene? Daglig? ○ Hvilke andre værvarsler/kilder bruker du? ○ Tenker dere det er forskjell på daglig varsling, og generell risiko for å bli truffet?	10-15 min
4	Felles bruk av vindparken ● Er is-kast en fare som dere mener omgivelsene er opptatt av? ○ Brukes området om vinteren (f.eks. reindrift, skigåere)? Ble det brukt før parken kom? ○ Snakkes det om iskast til daglig, for eksempel på butikken? ○ Virker folk bekymret? ○ Vet dere om varslene brukes (eller sendes de for å dekke en forpliktelse)? ○ Har dere andre typer varsler, f.eks. fysiske skilt? ○ Er varslene nyttig for dere når dere skal snakke med andre brukere av parken?	10-15 min

	• Har dere kontaktinformasjon til kjente brukere av parken?	
5	Hva er viktig å kommunisere i forhold til Is-kast? • Fargesystemet? • Daglig sannsynlighet eller generell risiko? • Hvilke kanaler brukes/ønskes av operatører, og av andre/private? • Push-varsling? • QR-koder på skilt i parken? • AR-løsninger? Lag i Google maps? • Forskjell om varselet kommer fra parken selv eller MET/NVE eller lignende?	(optional)
6	Avslutning • Noe dere ønsker å ta opp eller spørre om? • Kort oppsummering • Oppfølging - neste kontakt	5 min