Methods for evaluating risk caused by ice throw from wind turbines

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BBC News: Serbian minister hit by ice chunk

Source: BBC News 05.12.14

Ice – a significant safety risk

- Falling ice fatality potential
  - 40-60 J: Serious injuries to forehead
  - >80 J: Serious injury to body
- Impact energy depends on ice density, mass and velocity. Impact of 40 J corresponds to
  - 200 g of ice falling from 30-50 m
  - 500 g of ice falling from 5-6 m
- Special competence is needed to understand ice build up and shedding
- Damage potential depends on surroundings

Example of accumulated ice at Tryvann communication mast, Oslo, 2014.

Source: TNO Greenbook, CPR 16E, TNO ,1992

Current standard for safety distances is too simple

- Commonly used safety distance rule for icefall from an operational wind turbine

$$\text{Safety distance} = 1{,}5 * (H+D)$$

where

H = hub height of wind turbine

D = rotor diameter

- Our simulations and observations have shown that the actual safety distance may be both longer and shorter

Ice chunk of around 1 kg, observed at Norwegian wind farm.

Source: IEA Wind 2012, Kjeller Vindteknikk

Precise mapping of ice risk – site specific approach

Metrological study

- Probability of ice in construction
- Estimated size and weight distribution of falling ice

Risk assessment

- Site risk for personnel operating the facility and third parties
- Individual risk for different exposures, e.g. pedestrians and vehicle passengers

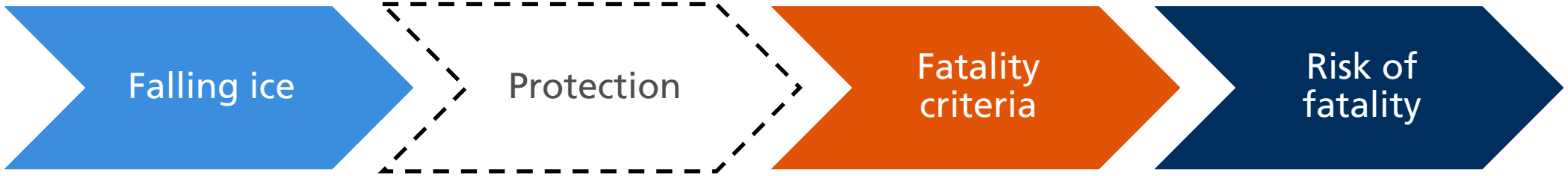
Acceptance criteria

- Proposed criteria for different safety zones
- Based on Norwegian Directorate for Civil Protection (DSB) guidelines
- Final, site specific criteria determined by installation owner (or by law where applicable)

Risk reducing measures

- Recommendations for risk reducing measures
- Meteorological forecasting of ice throw probability

Probability distribution of falling ice used to map risk of fatality



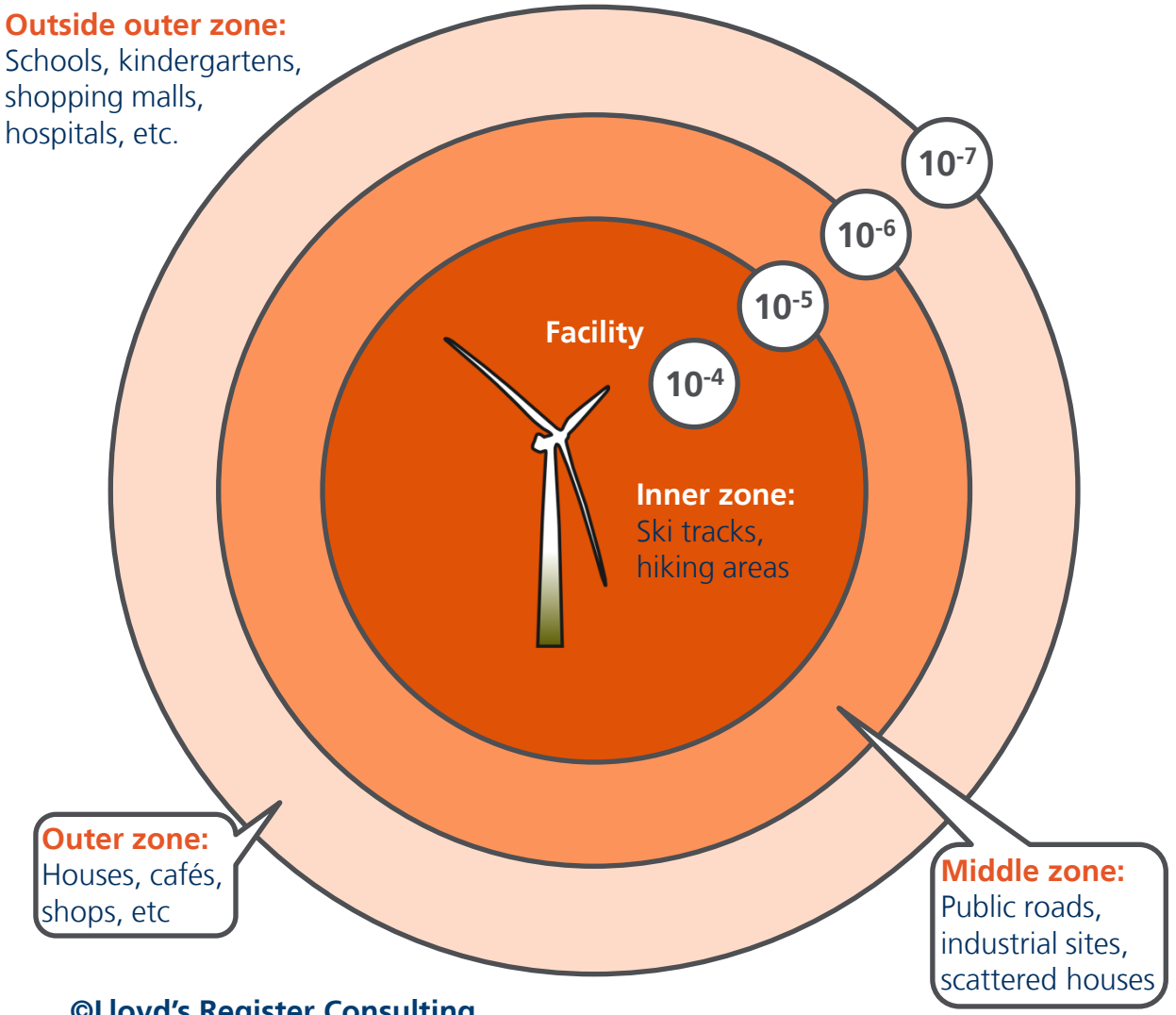
- Calculated distribution of falling ice per square meter
- Estimated energy per ice cube

- Tunnels etc. may provide 100% protection
- Car: 10% risk of ice hitting wind screen, 140 J required to penetrate windscreen

- 10% risk of person being hit (covers area of ~20cm x 50cm) per square meter
- Potentially fatal if energy > 40 J

- Map of annual probability for loss of life (PLL) due to falling ice from facility

Suggested acceptance criteria for third person



- Key principle: Facility should not increase risk to public significantly compared to daily risk in society
- Acceptance criteria are given as annual probability for loss of life (PLL) caused by the facility
- Exposure time is factored into the acceptance criteria
- Based on Norwegian Directorate for Civil Protection (DSB) guidelines
- Higher risk may be accepted for personnel operating the facility, given sufficient knowledge and routines to handle the risk

Risk reducing measures

- Ice fall risk is typically concentrated to a few, short periods per year
  - Meteorological forecasting
  - Ice sensors

- Risk reducing measures for third party
  - Clearly visible warning signs
  - Fencing around area, locked gates
  - Limit public activities
  - Re-routing of footpath, ski tracks etc.

- Risk reducing measures for operating personnel
  - Protective grids, roofs or tunnels
  - Personal protective equipment (PPE)

Warning system at Tryvann communication mast, Oslo, 2015.

Benefits from our approach

- Ensure safety by design
- Optimize installation footprint

Project developers

- Increased certainty and understanding of risk level
- Solid documentation of the impact on the surroundings

Installation owners

- Ensure a safe working environment
- Minimize negative effects on third parties

Operators

Explore our services

- Risk assessments and consequence modelling
- Recommended safety zones
- Recommendations of risk reducing measures
- Meteorological simulations
- Ice forecasting and warning systems
- Human factors and safe behaviour studies

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Recent example of results from Norwegian wind farm