
AFRY

Simulating ice throw risks in wind and hybrid farms

Monte Carlo simulations, icing modelling and probability calculations

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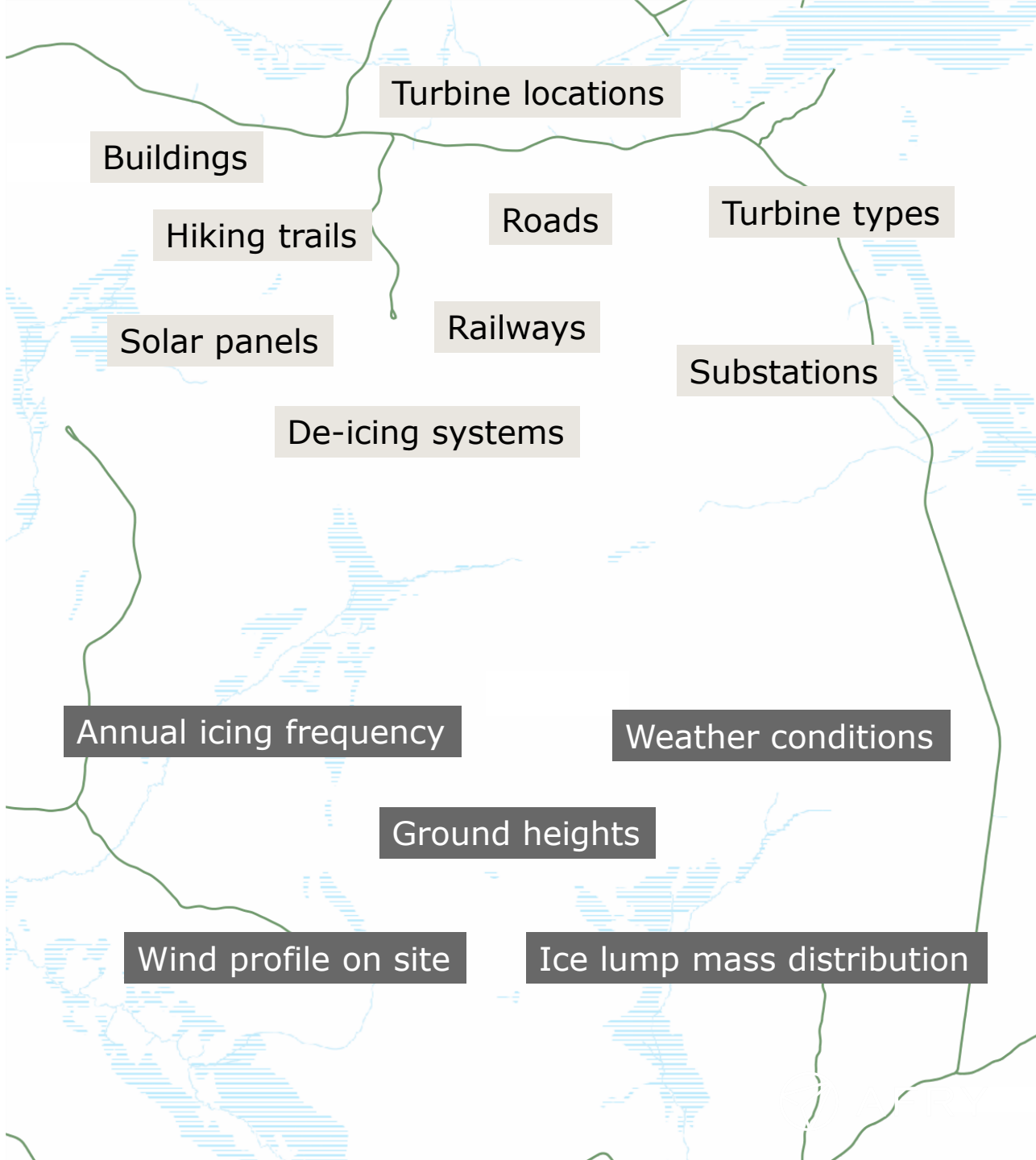
Contents

Introduction to ice throw

- Ice particles falling from the operating wind turbines
- Particles can fall all around the turbines depending on turbine position, wind direction, wind speed and other conditions
- Problems related to icing:
  - production loss
  - increased maintenance cost
  - reduced technical life of turbines
  - safety risks
- Risks of a fatal accidents must be on an acceptable level

Objectives and initial data

- Why to simulate ice throw?
- The target is to estimate the annual risks to humans, property or infrastructure, related to ice throw from the turbines
- The results can be used to
  - determine a need to mitigate risks or
  - inform people of the possible danger or
  - estimate the costs related to broken property.



Simulation methods

— ICETHROWER-study* was made in Sweden ten years ago and the results were used to make the original simulation

— The simulation model is based on the study results and Monte Carlo –simulation

— The model considers the ice lump mass distribution, wind profile in the area and ground height in the turbine surrounding

— The tilt angle of solar panels or other structures can be considered

— Annual icing frequency is needed

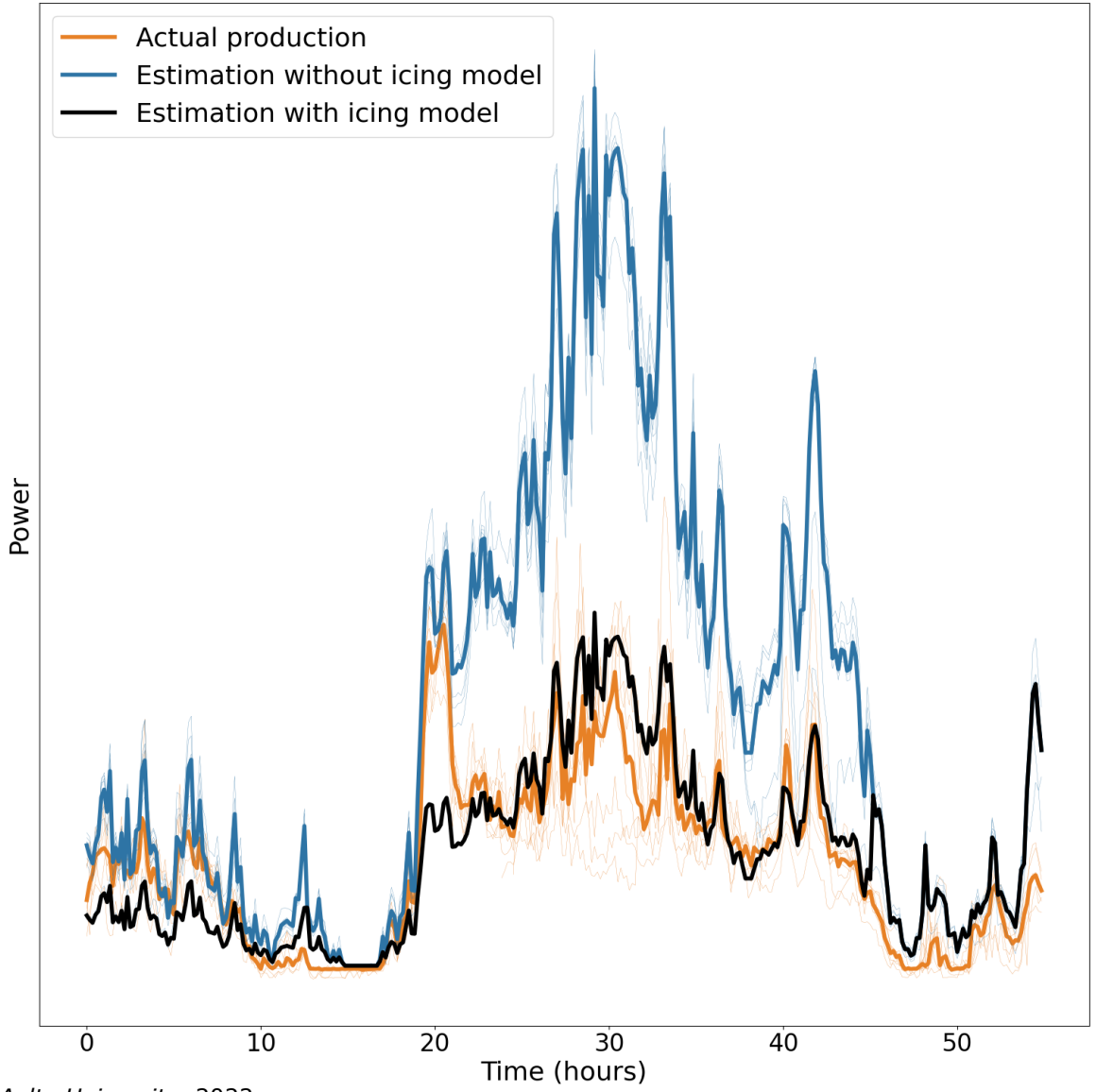
*ICETHROWER – mapping and tool for risk analysis, Swedish Energy Agency, 2017.

Icing assessment

- Can be applied to estimate the hourly or annual icing frequency on a certain site
- Based on ice accretion physics*

$$\frac{dM}{dt} = \alpha_1 \alpha_2 \alpha_3 \cdot w \cdot A \cdot v$$

- Model parameters are optimized for each wind farm and icing type**
- Focuses on the releasing point of ice, which is critical for ice throw
- Assessment approach used in AFRY's day-ahead prediction system (DAPS)



*ISO 12494. (n.d.). *Atmospheric Icing of structures, International Standard, ISO/TC98/SC3/WG6.*

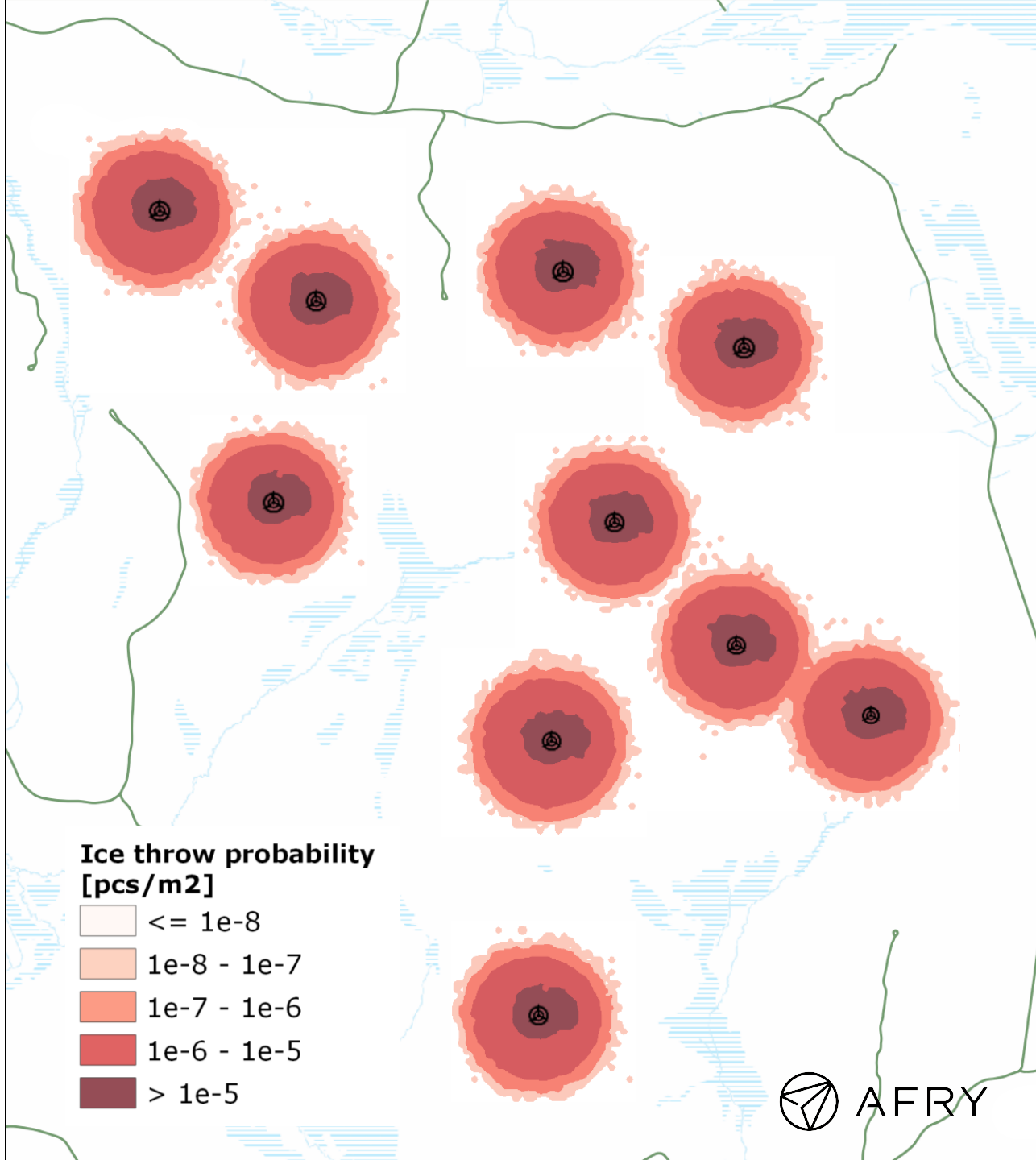
**Helmi Uusitalo: *Analysis and Modeling for Predicting Icing Losses in Finnish Wind Power Production*, *Aalto University*, 2022.

Simulation results

— Simulations are run to determine ice lump landing probability around turbines

— In the probability map, ice throw hit risks are shown for the turbine surroundings

— Probability map results can be used to calculate specific risks to people or structures in a certain location



Risk calculations

— The risks are calculated using probability distribution around turbines, annual icing frequency and the projected area of the object

$$R = n_i \cdot n_e \cdot p_h \cdot A$$

— Calculations are determined as specific for each site depending on the assumed risks

— Recommendations are made based on the calculation results

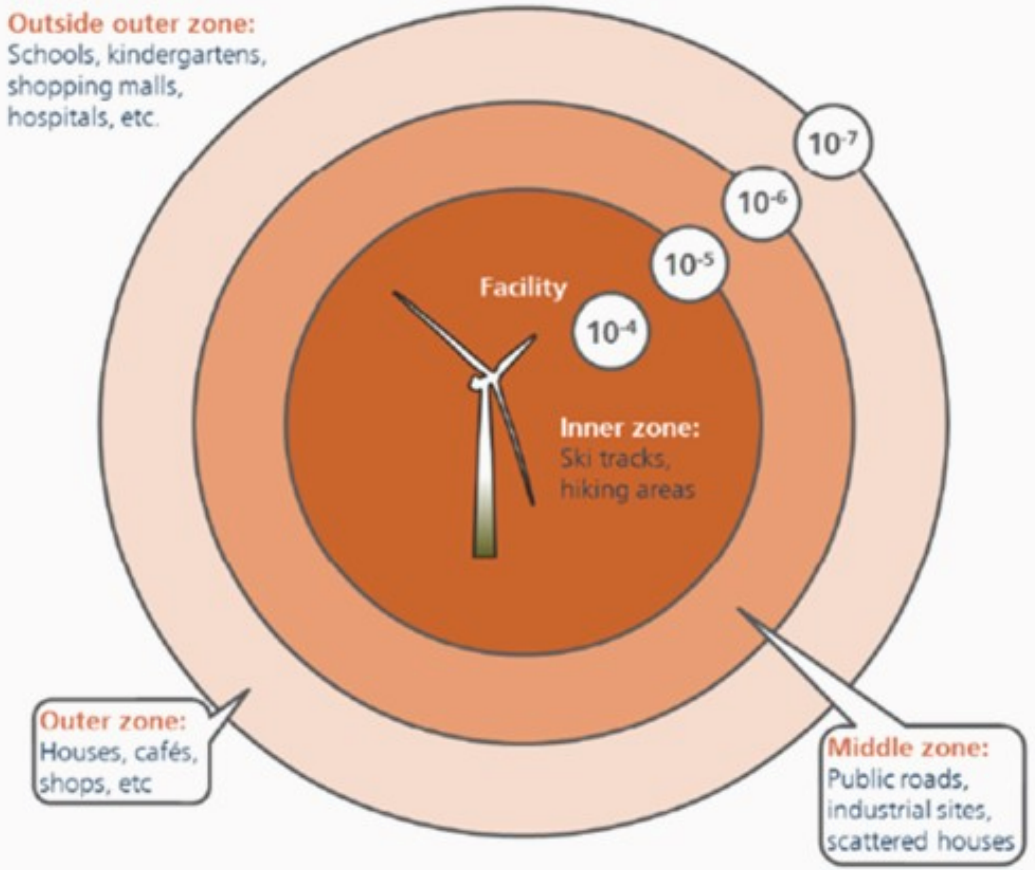
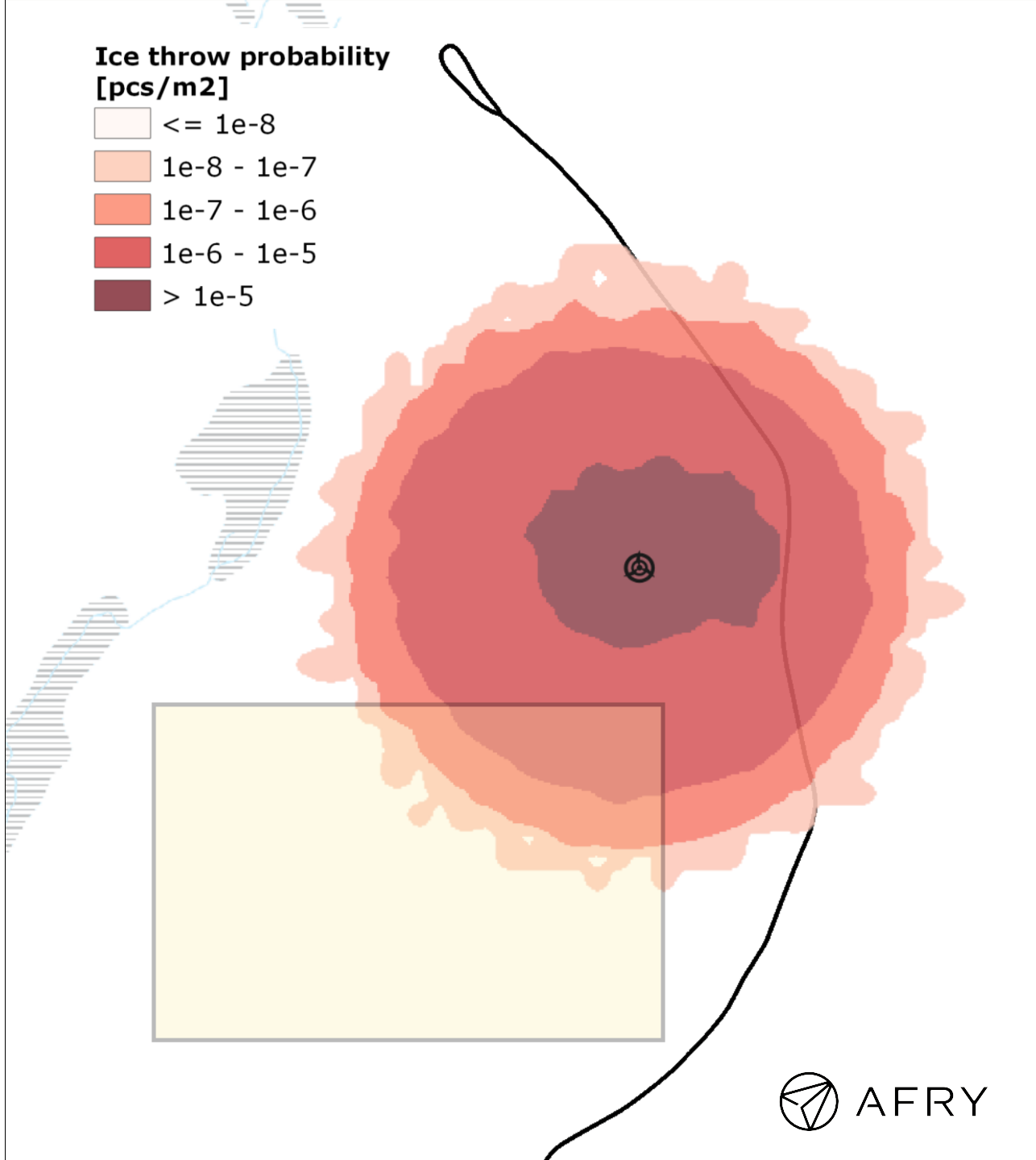


Figure: IEA Wind TCP Task 19:
International recommendations, IEA Wind, 2018.

Hybrid farm application

- As the hybrid farms with both wind and solar power generation are becoming more common, it is relevant to know the ice throw risks related to solar panels.
- Annual average of ice hits to solar panels can be determined using:
  - Site-specific assumed ice hit frequency
  - Location of solar panel area
  - Solar panel density in panel area
  - Solar panel tilt angles
  - Solar panel orientations
- The results can be used to optimize the solar panel siting
- Same methods can be applied to other tilted and oriented structures on site



Conclusions and summary

— Evaluating ice throw risks is important for determining and minimizing safety risks for people, property and infrastructure

— Simulations and risk calculations help to estimate the need for informing people moving in the area or protect valuable structures or safety considerations in the land use planning

— Assessment can be utilized either in development phase or for operating wind farms