

The economic costs of icing and the potential of icing forecasts:

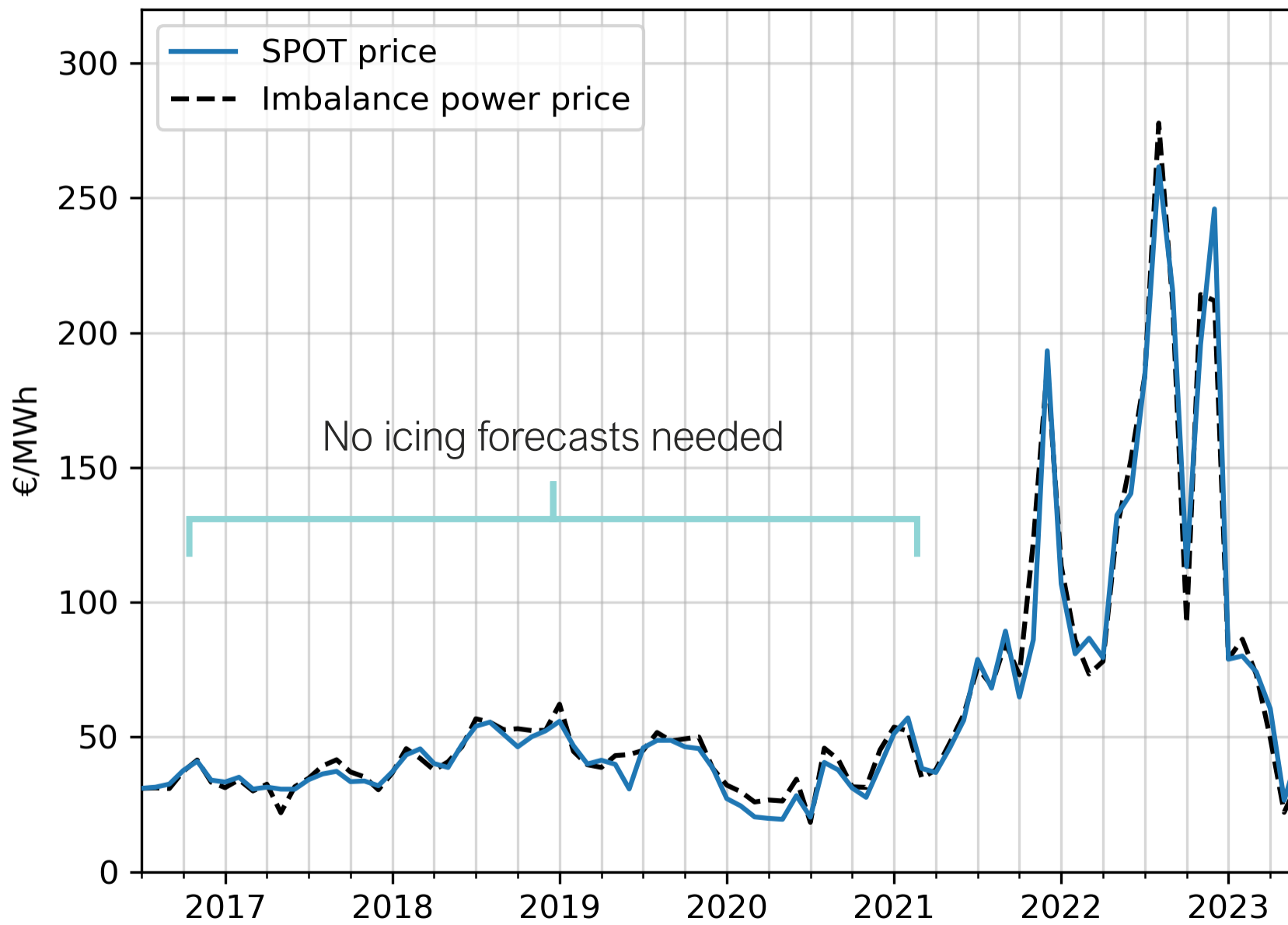
A case study in Finland

Mona Kurppa, Kjeller Vindteknikk

WinterWind 2024, Åre, Sweden

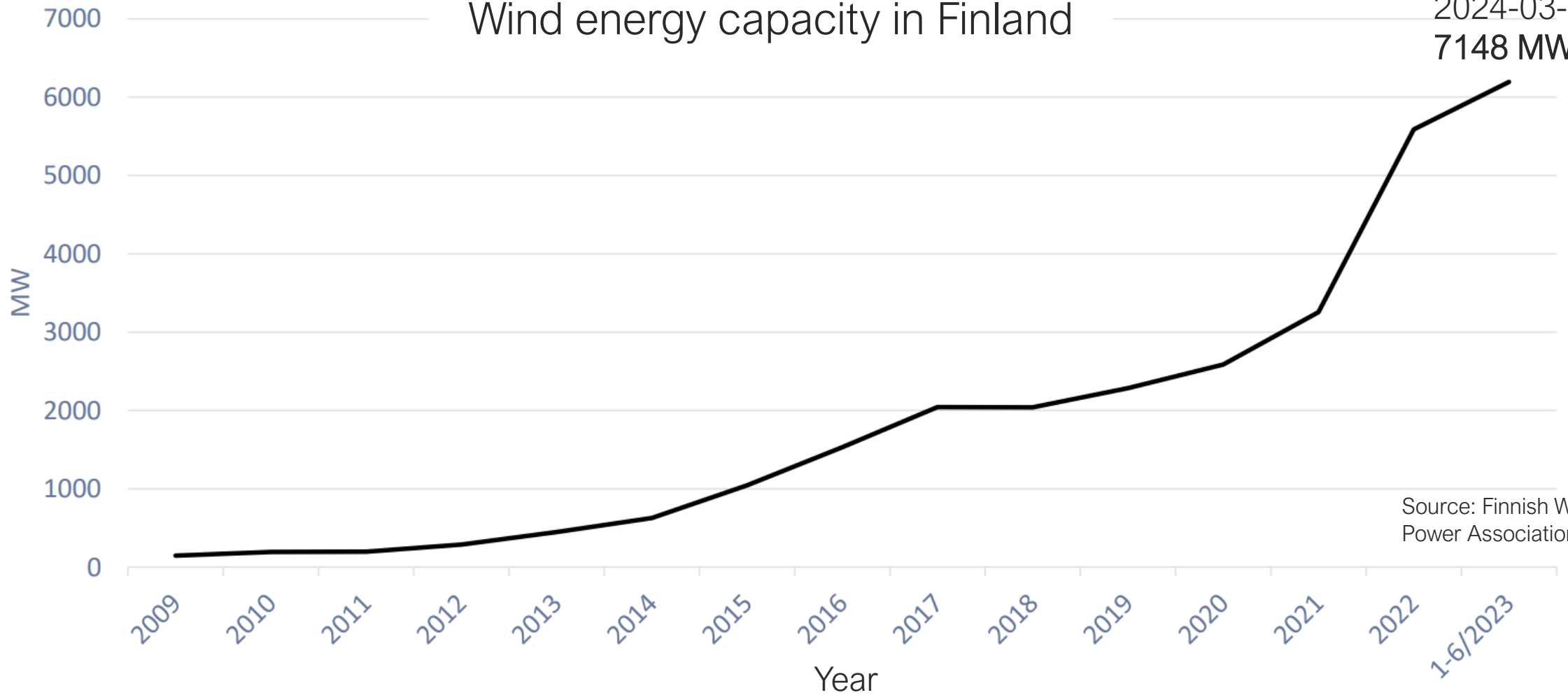
Why would we need icing forecasts?

Monthly mean electricity prices in Finland



Wind energy capacity in Finland

2024-03-18:
7148 MWh



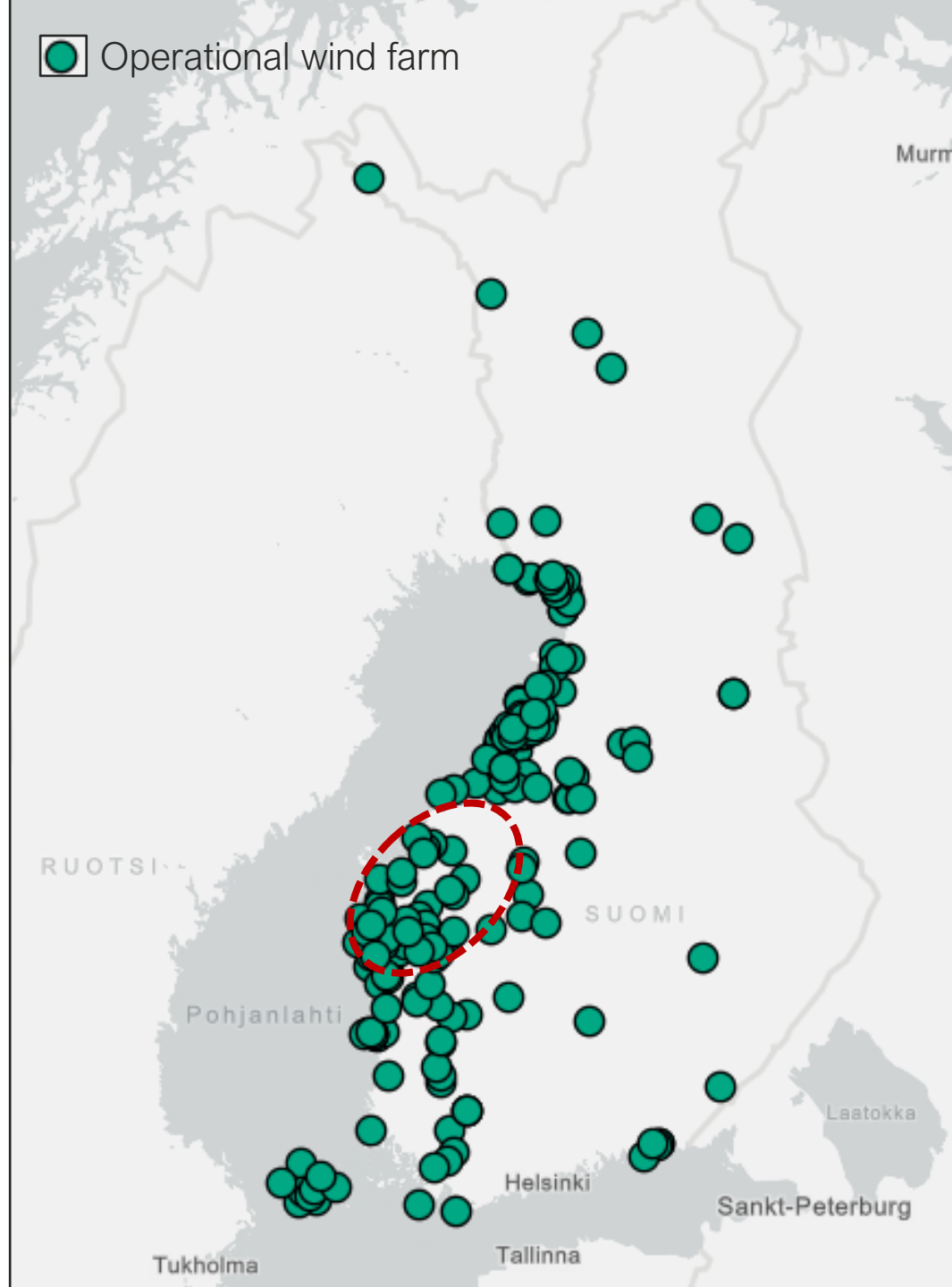
Source: Finnish Wind Power Association

Case study

- I. What are the costs of icing?
- II. What are the benefits of using an icing forecast model?

Example wind farm

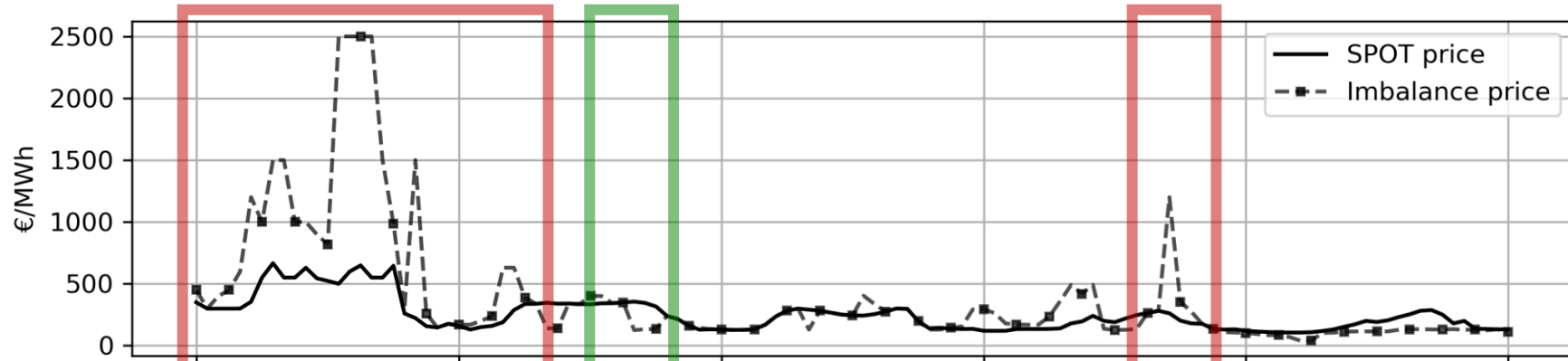
- Total 50-80 MW
- Number of turbines: 15-25
- Located in South Ostrobothnia
- SCADA data: 7 years
- Assumption: Buys all the missing production from the imbalance market



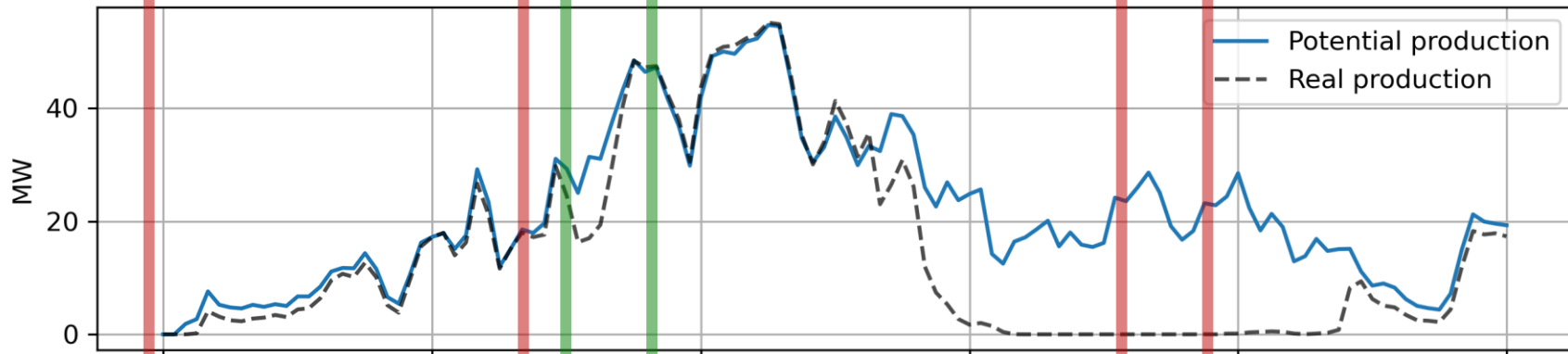
Example of the SCADA timeseries

December 2021

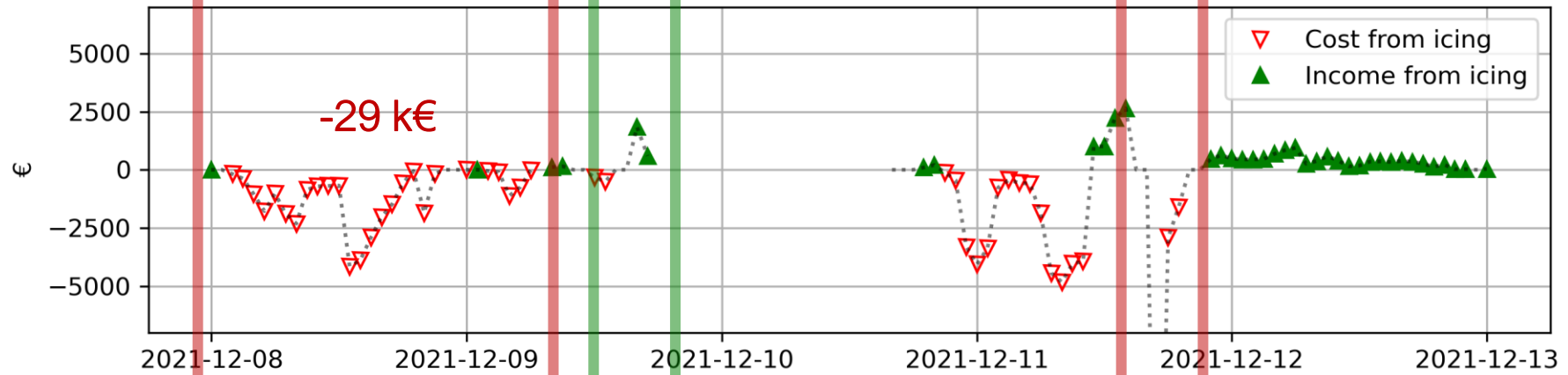
Electricity prices



Power production (SCADA only)



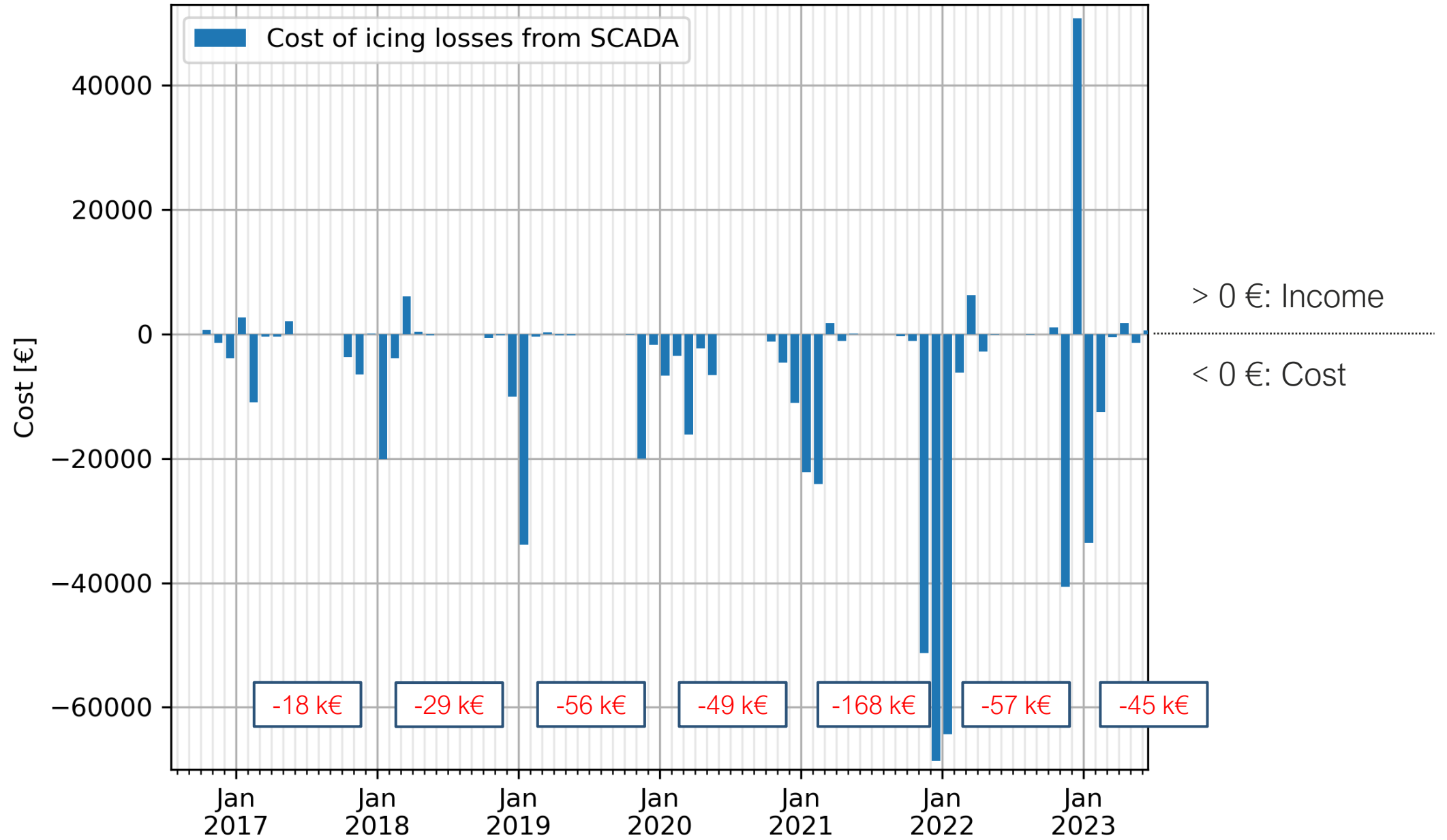
Real costs / income during icing



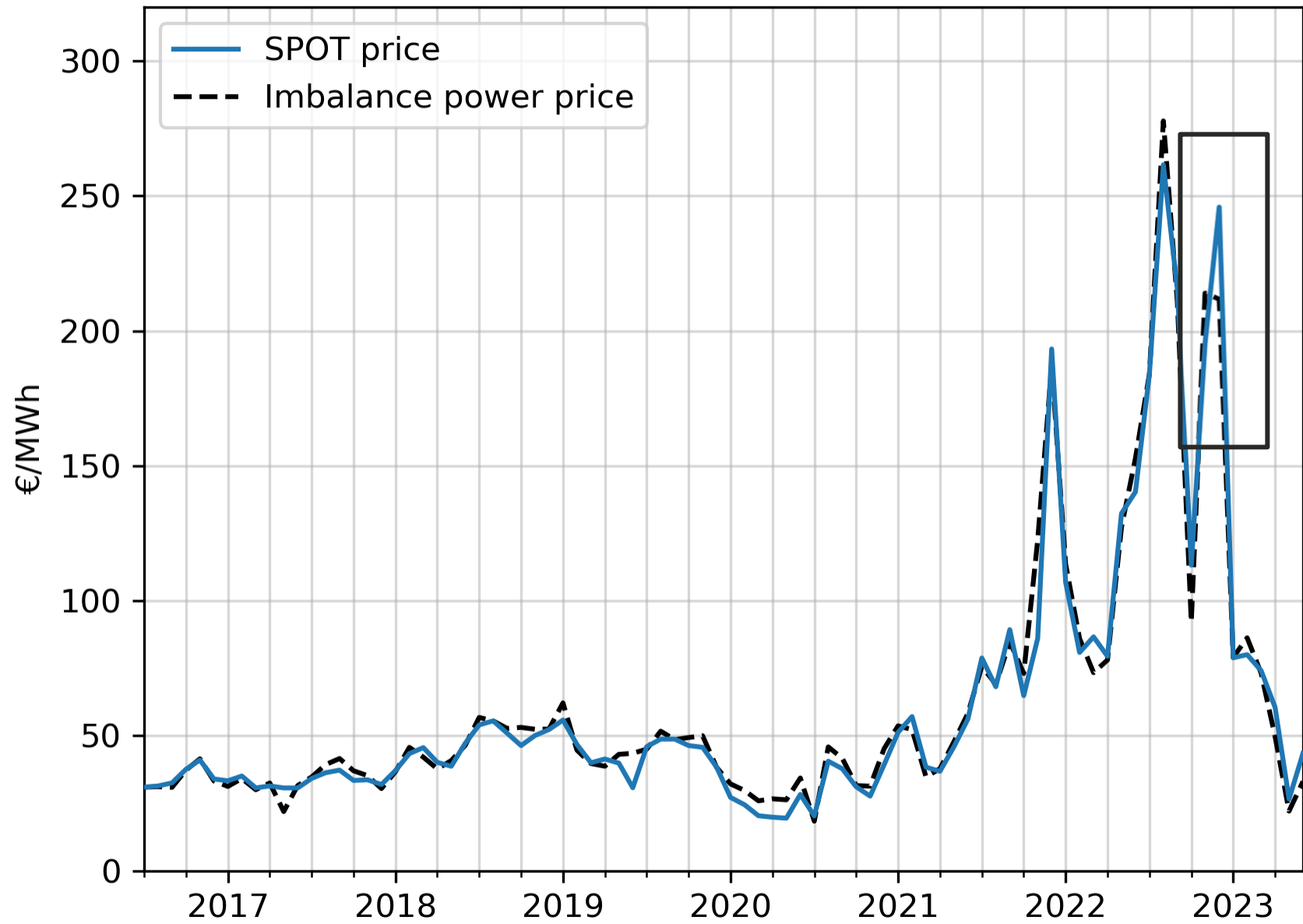
Assumed that the wind farm has a perfect wind forecast!

Only periods of icing and full performance are included!

Cost due to non-produced MWh



Monthly mean electricity prices in Finland

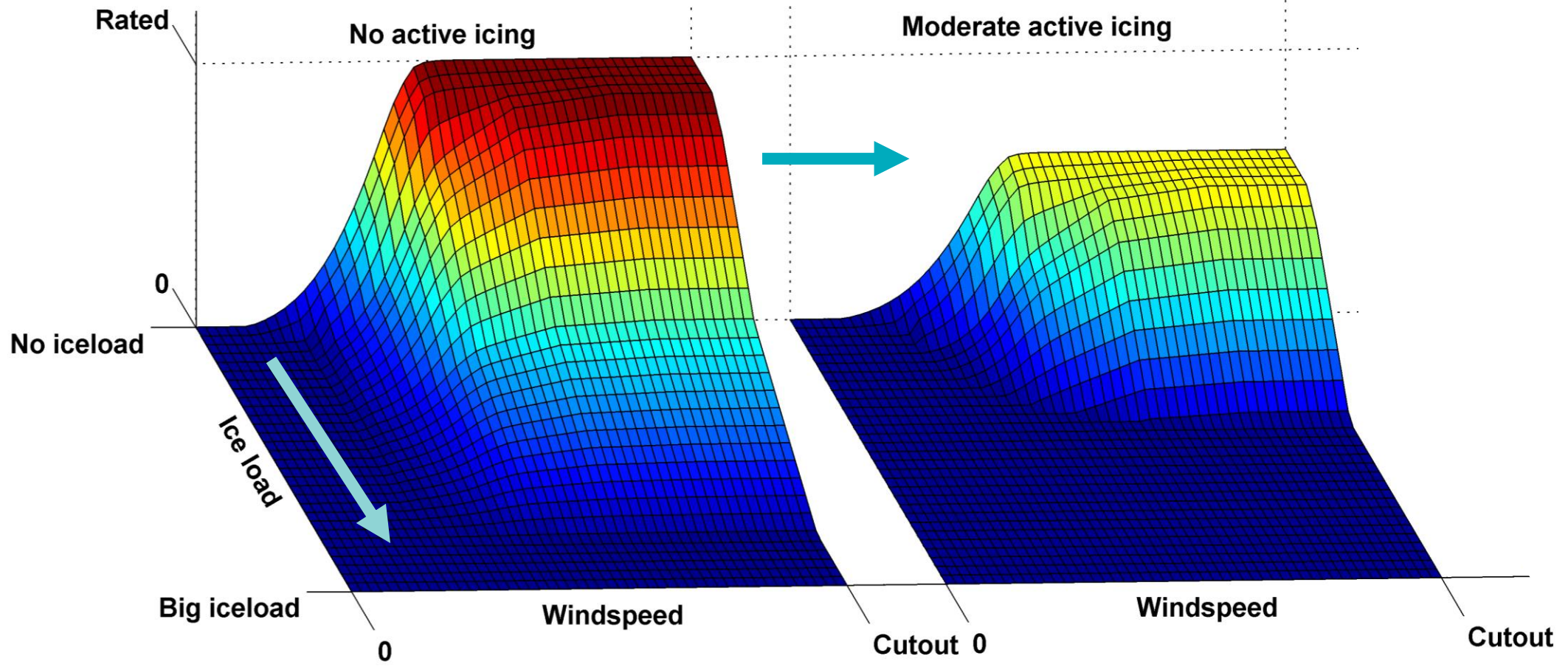


Dec 2022 was exceptional: high SPOT and large differences between SPOT and imbalance price

IceLossForecast model

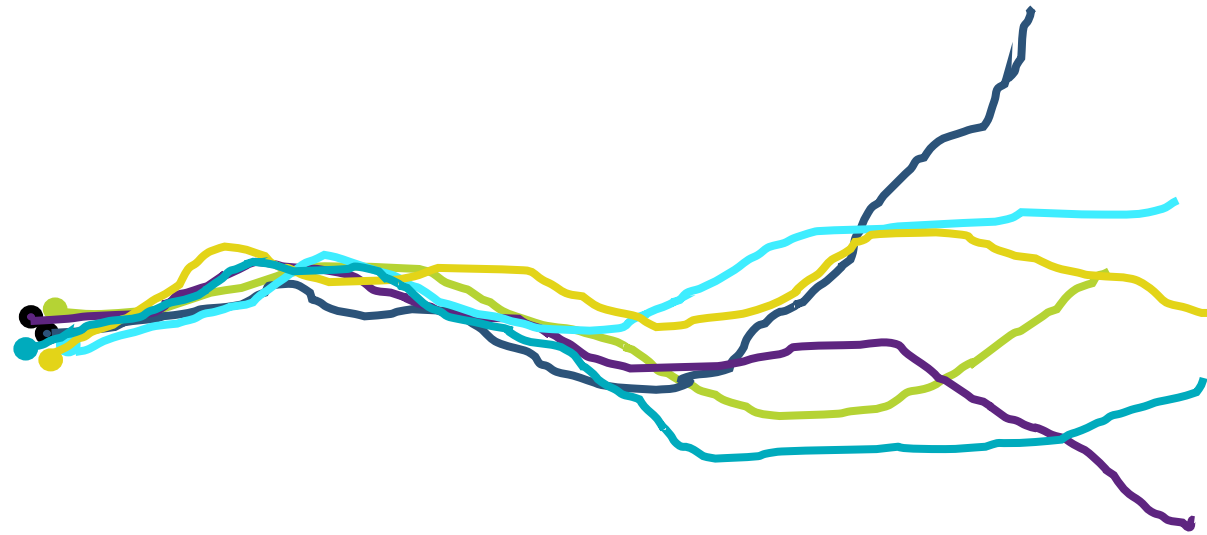
- Model:
 - Based on IceLoss model* since 2009
 - Physical icing model
 - Input: 48/56-hour WRF forecast data, updated every 6 hours
 - Output: Icing on blades and production loss due to icing
 - Operational for 23 WFs + Fingrid (whole Finland) in 2023-2024
 - Simulations:
 - No ice model: Icing loss is always 0%
 - Normal IceLossForecast simulation
 - Ensemble simulations → Probability of icing
- } No SCADA tuning!

*: WW23: Simo Rissanen



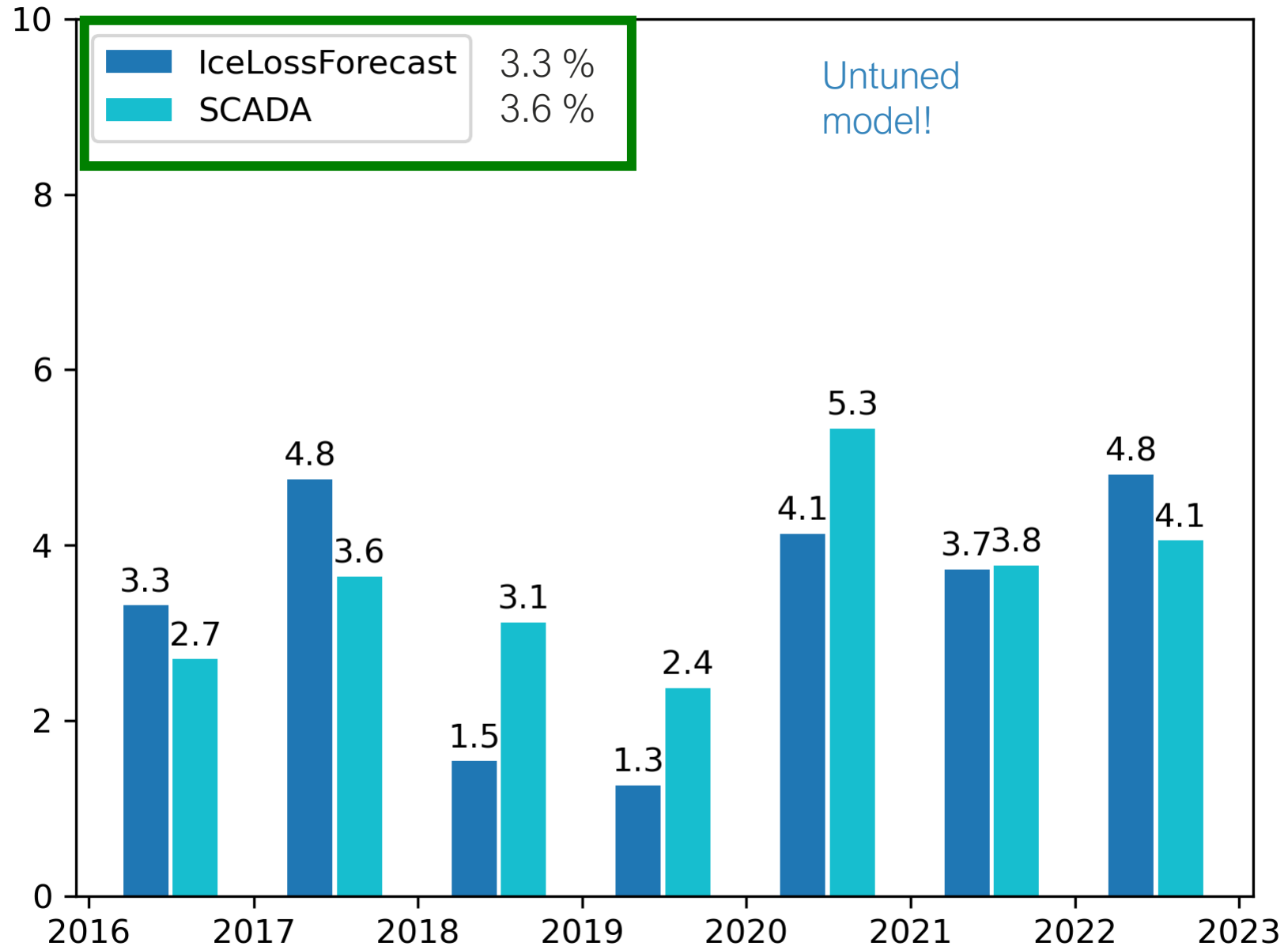
Normalised power 

Ensembles \rightarrow Probability of icing

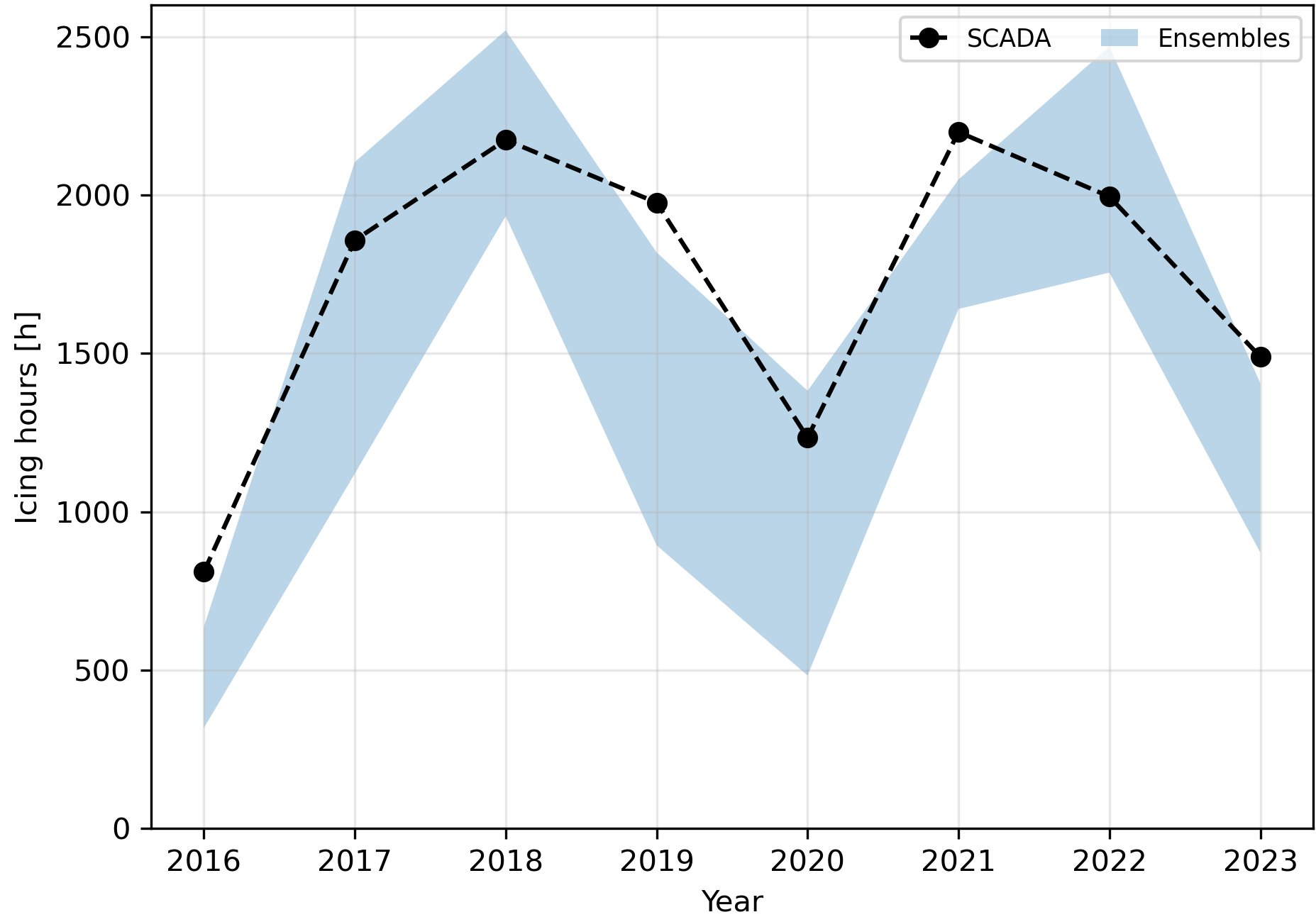


SCADA vs. IceLossForecast

Annual total
production
loss due to
icing [%]

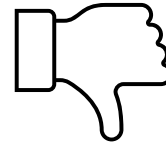
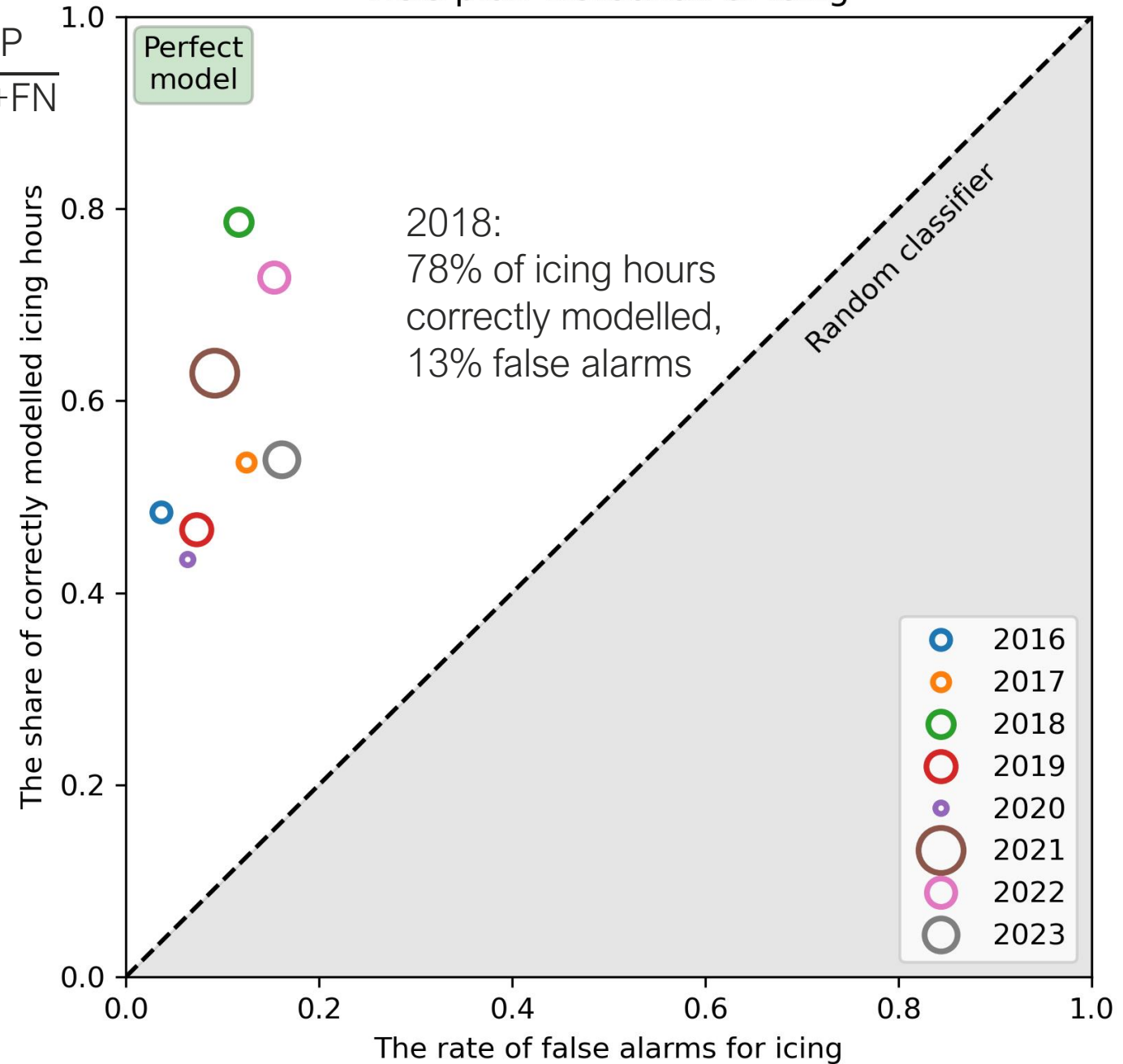
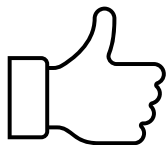


Annual icing hours (sum)



ROC plot: Detection of icing

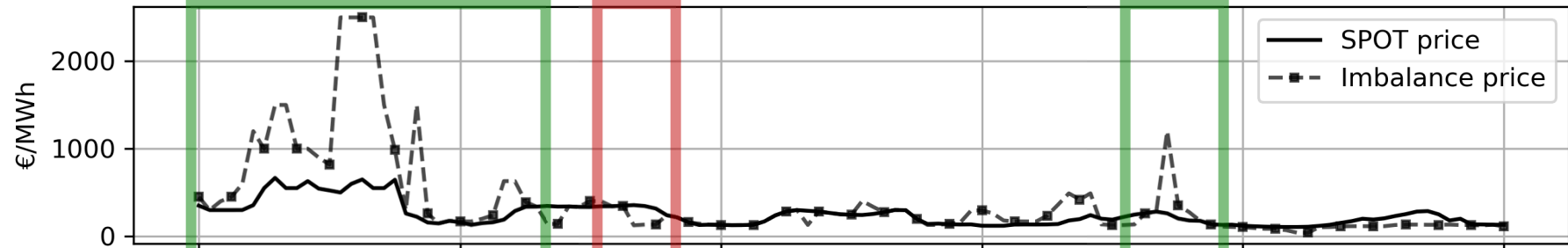
True positive rate = $\frac{TP}{TP+FN}$



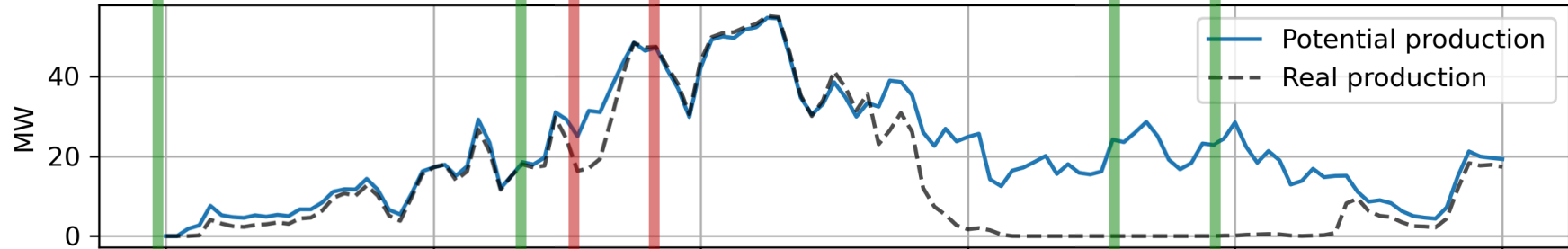
False positive rate = $\frac{FP}{TN+FP}$

December 2021

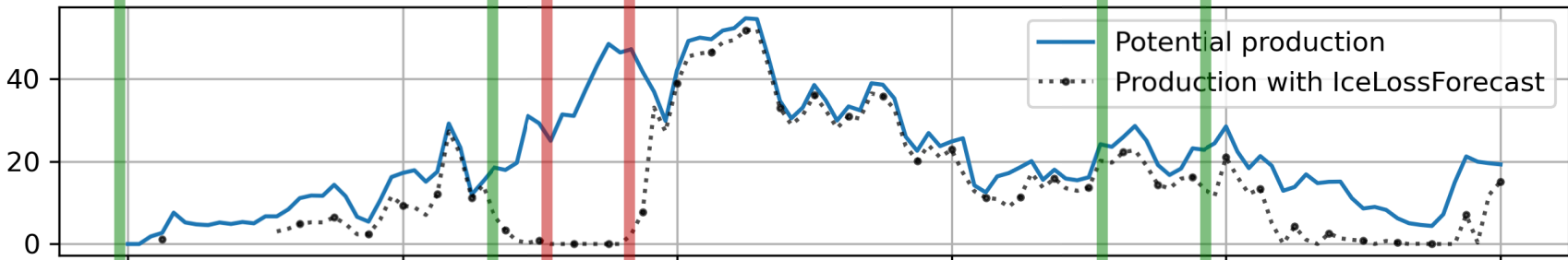
Electricity prices



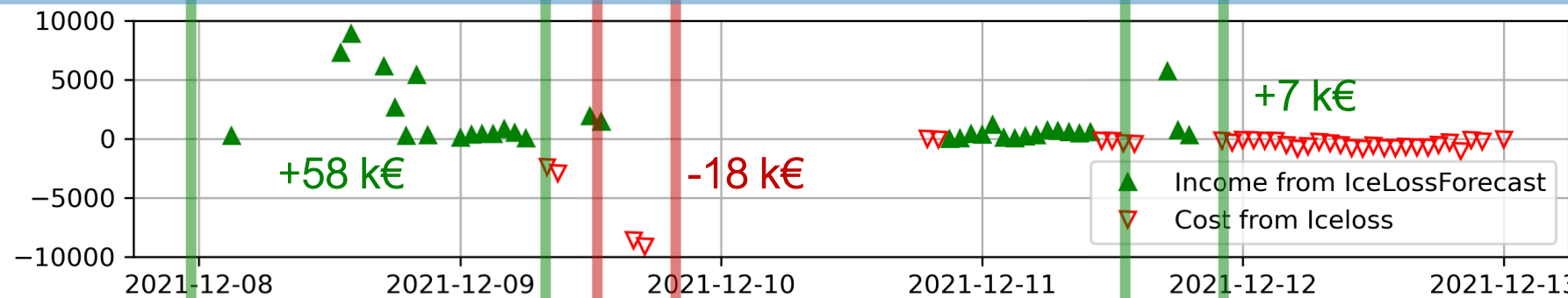
Real production



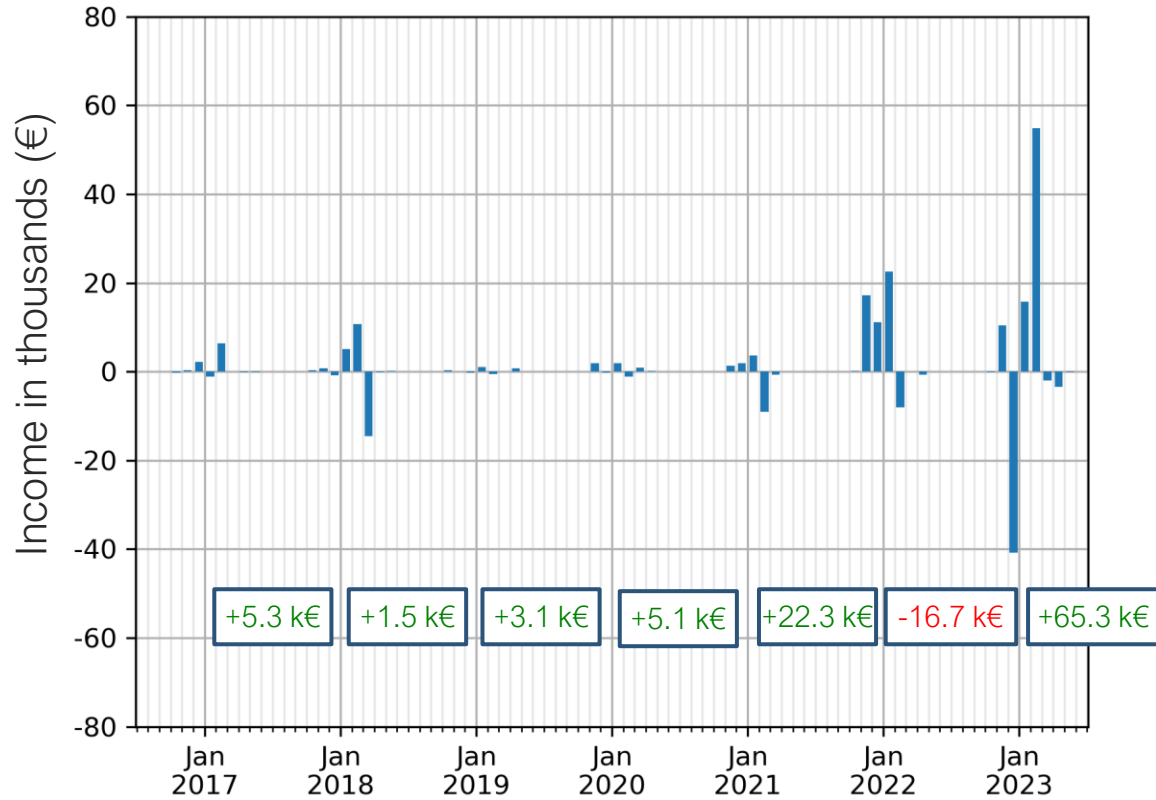
Production with IceLossForecast



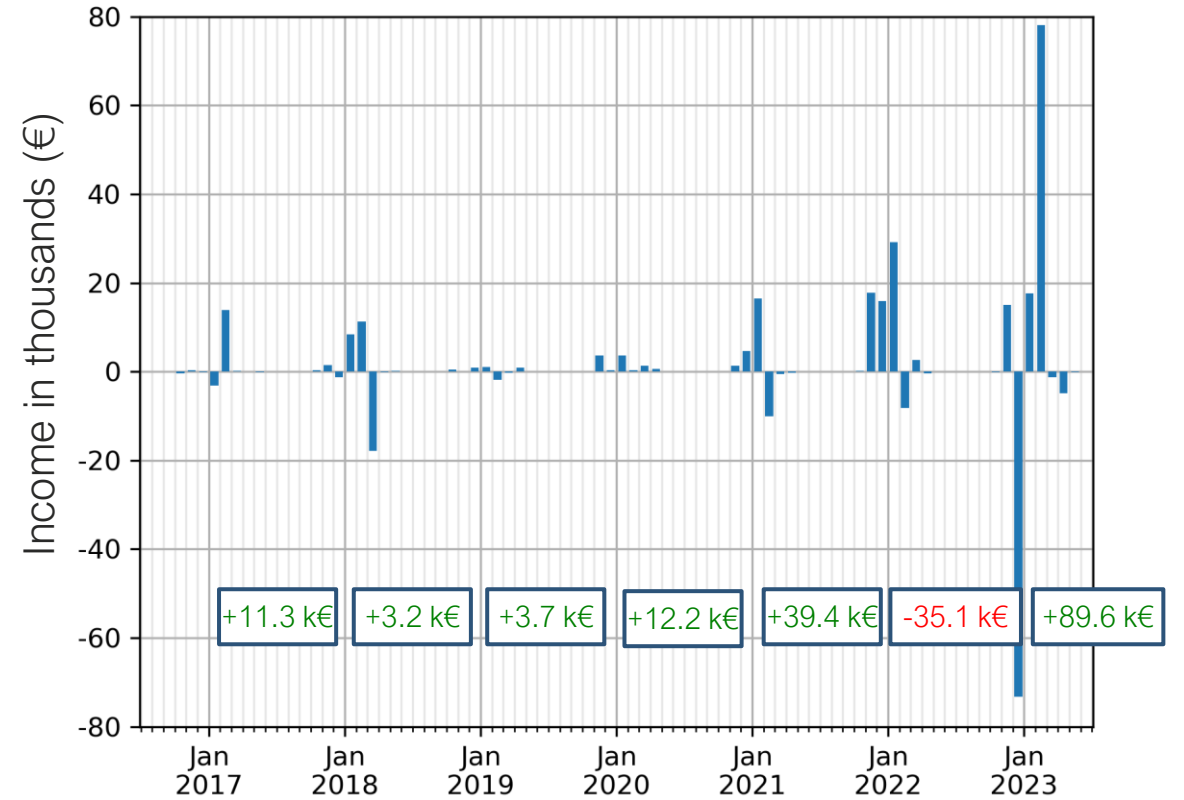
Income / cost from IceLoss



Normal IceLossForecast simulation



Best ensemble member



	Cost of icing 7/2016-6/2023	Difference to “No ice model”
No ice model	-426 k€	-
Normal IceLossForecast simulation	-337 k€	+88 k€
Best ensemble member	-301 k€	+124 k€

Summary

- Accurate icing forecasts needed
 - Energy prices and its fluctuations have increased
 - More wind energy
- Icing creates high economic costs but can also lead to income
 - Income during energy market disruptions
- Applying IceLossForecast model by KVT decreased icing-related costs by 20-30% at the example wind farm

Norconsult 

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