Advances in icing forecasts using machine learning

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Winterwind 2019, Umeå

Presented by Till Beckford

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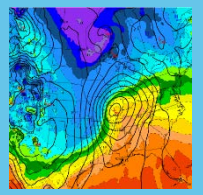
Background - Forecasting Summary

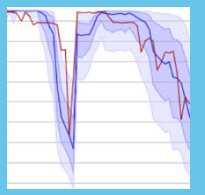
Wind, solar and power demand forecasts

5 minutes to 15 days into the future

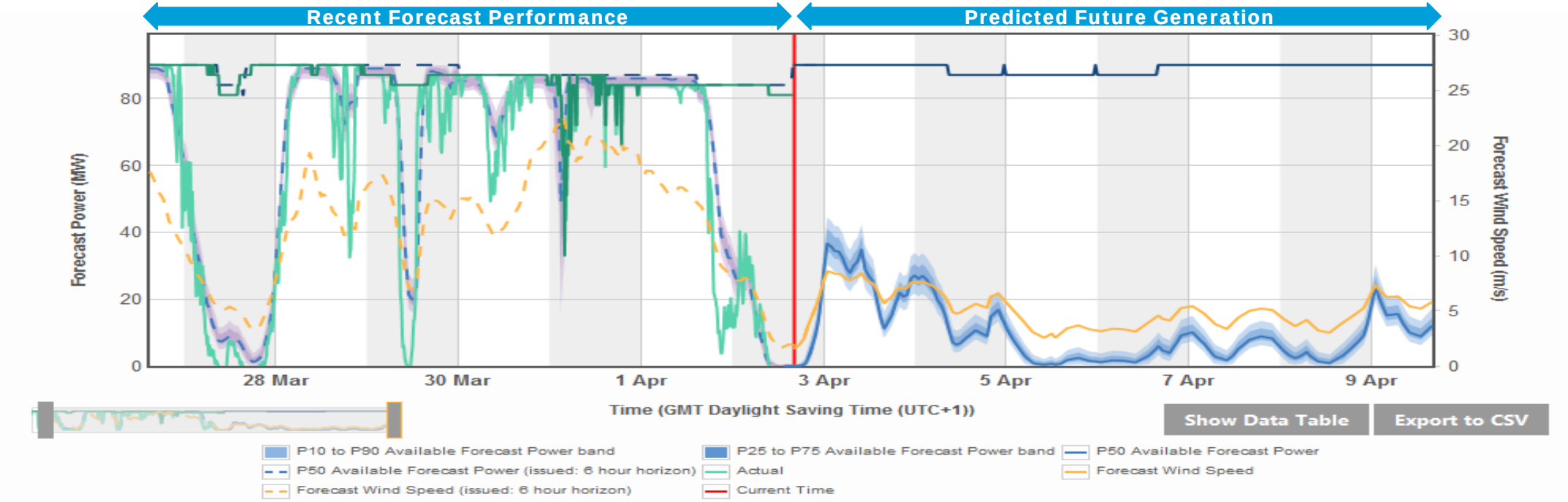
Global Experience
> 50 GW capacity
> 20 countries



Data from the World's best forecast models



Accurate uncertainty data for risk evaluation

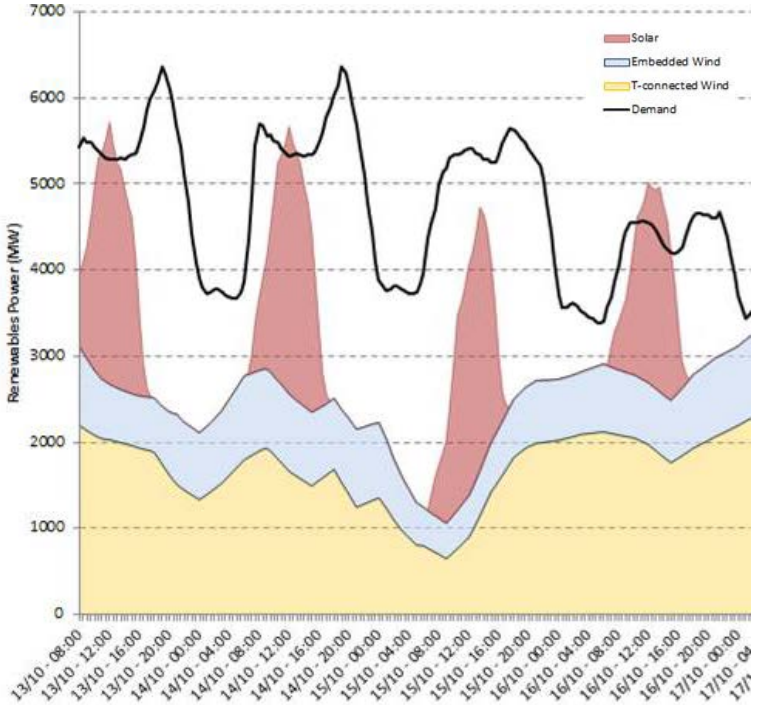


Background - Reducing Risk through Forecasting

Energy Trading

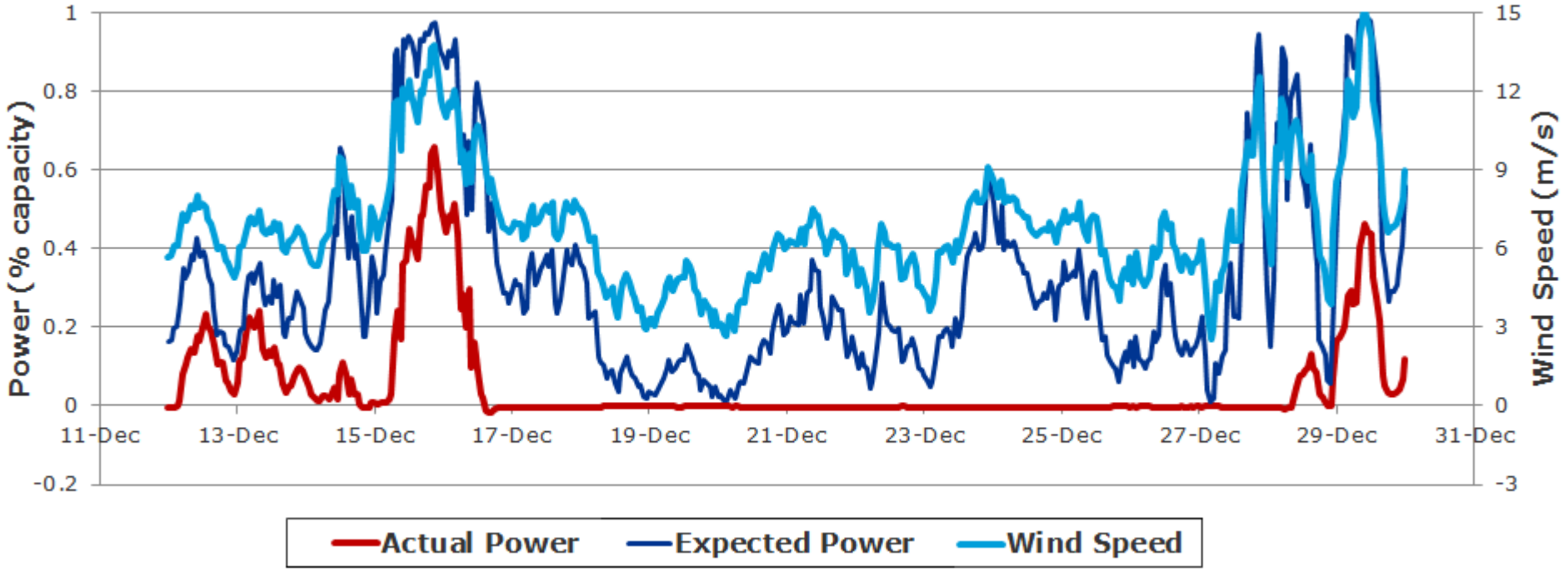
Optimised operations & maintenance

Generation scheduling and grid operation

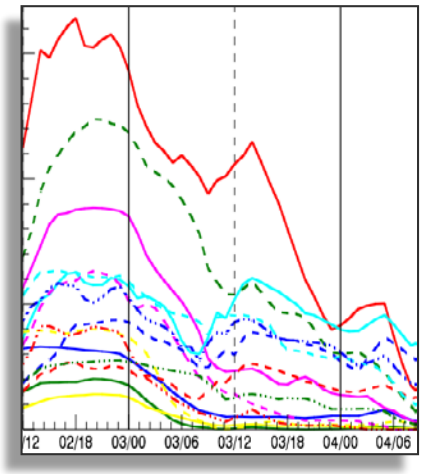


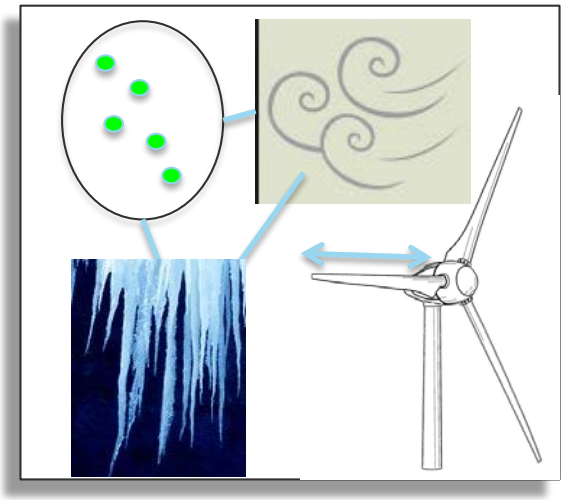
Background – Icing Forecasting

- Energy production losses can be >10% per year, >50% per month
- Icing events → sudden full loss of power
- Impacts power forecast accuracy and O&M

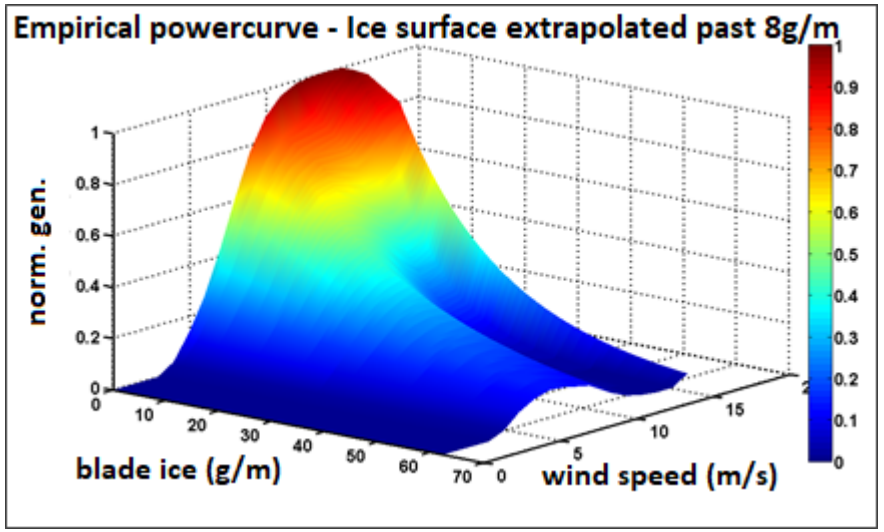


Previous icing model - Method

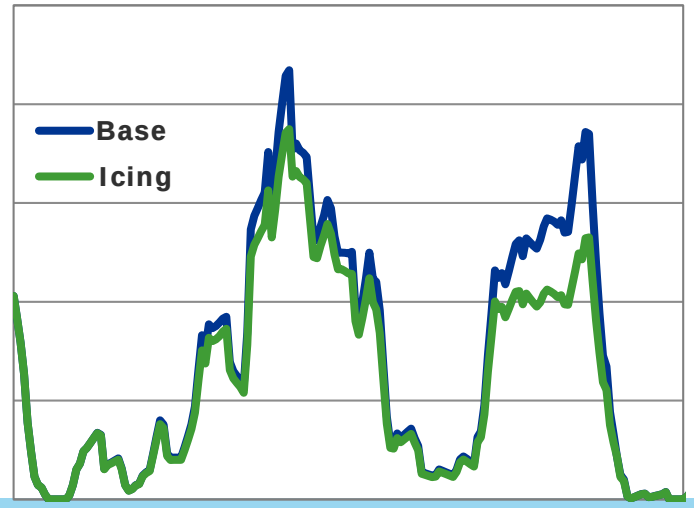




Adapted from Frohboese and Anders (2007)

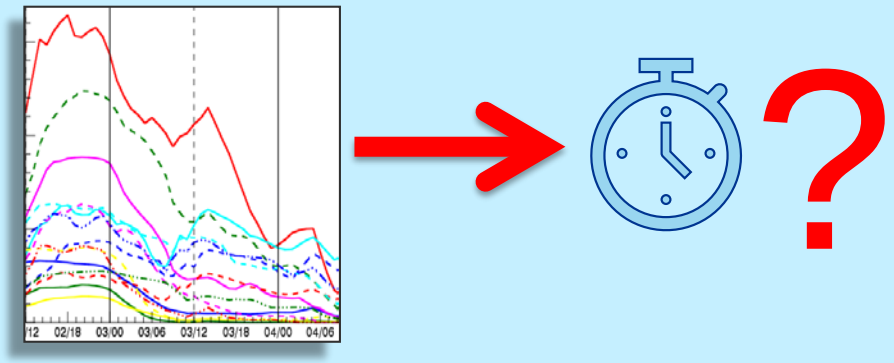


Borrowed from http://www.tuuliatlas.fi/icingatlas/icingatlas_6.html

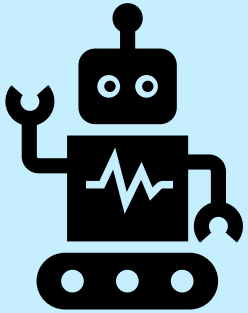


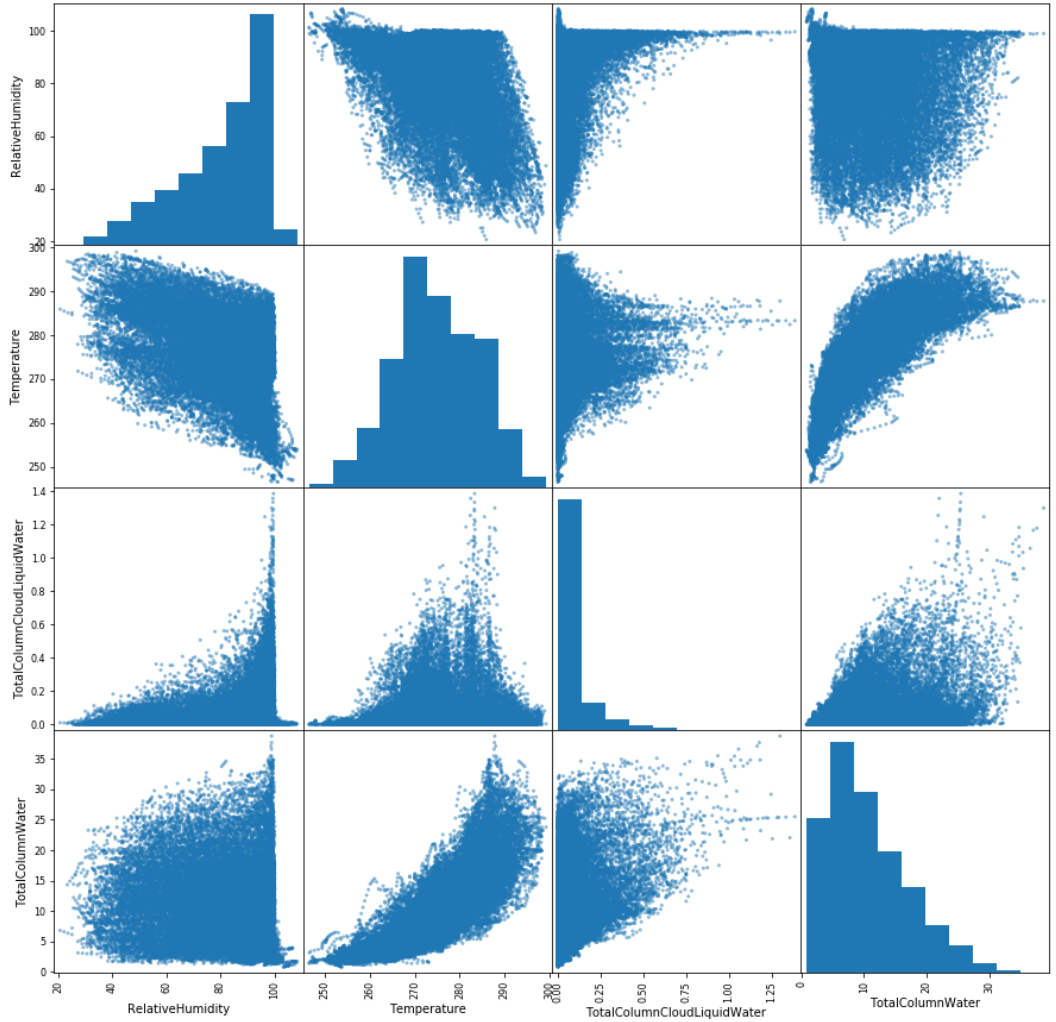
New icing model – Machine Learning

Largest error: When will icing occur?



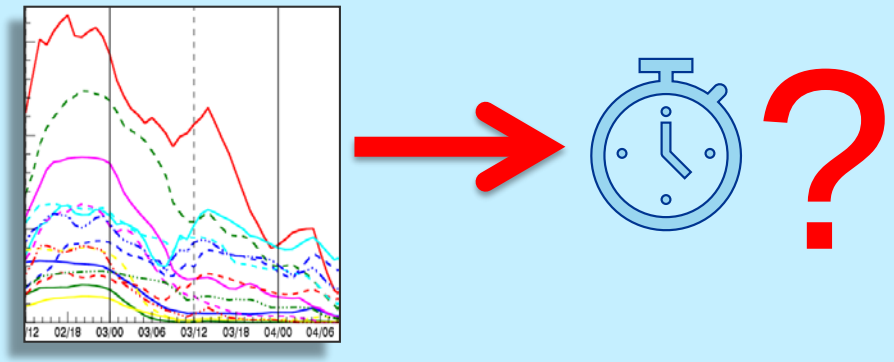
Solution – Machine learning



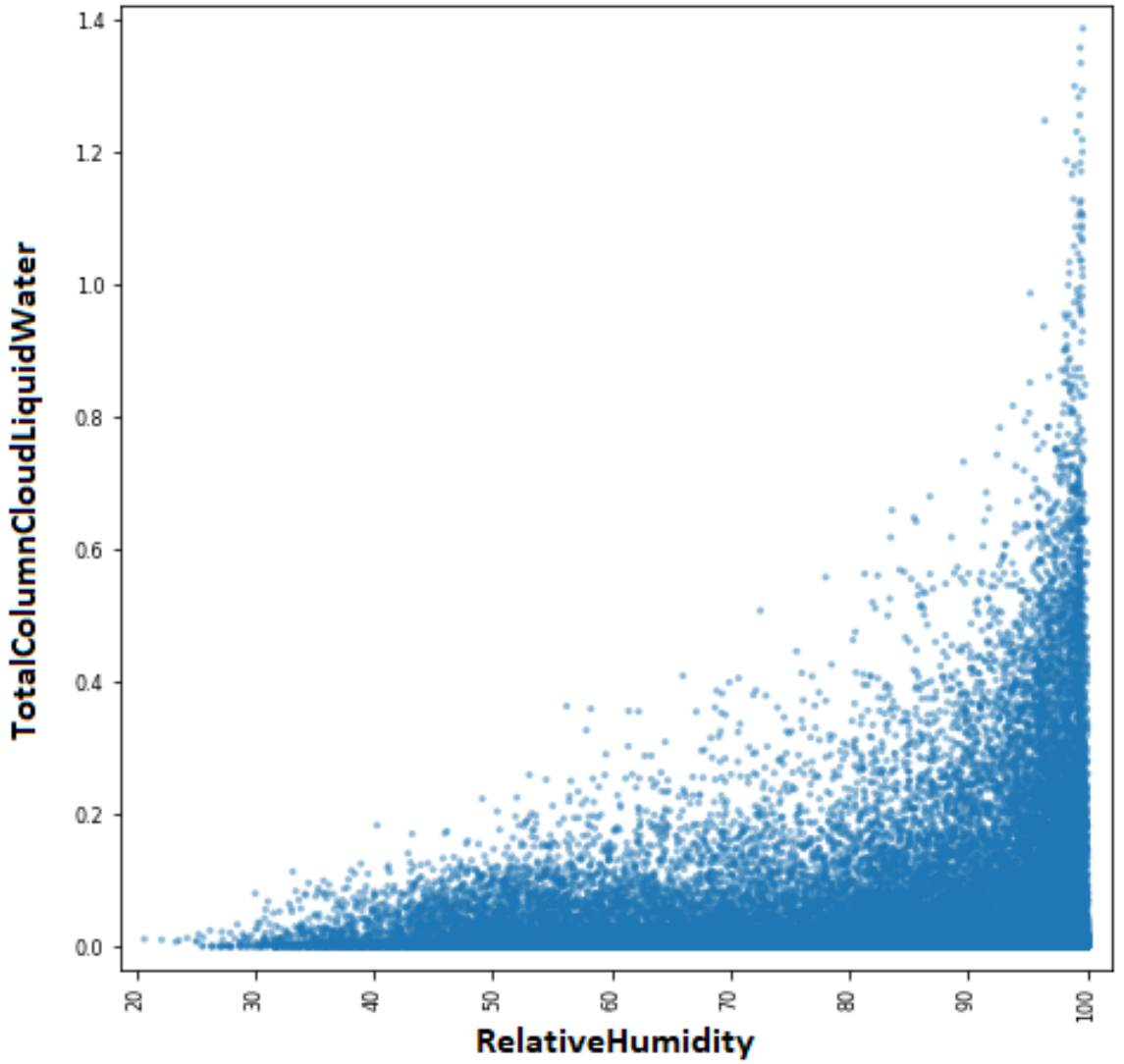


New icing model – Cloud Water forecast inputs

2nd error: How much water is there?



Solution – Liquid Water Content



Validation Data

- 3 wind farms, ~40 wind turbines
- Projects in mid Sweden where there is sufficient icing to test model
- For each site:
  - ~1 year of data for model training
  - ~1 year of data for validation

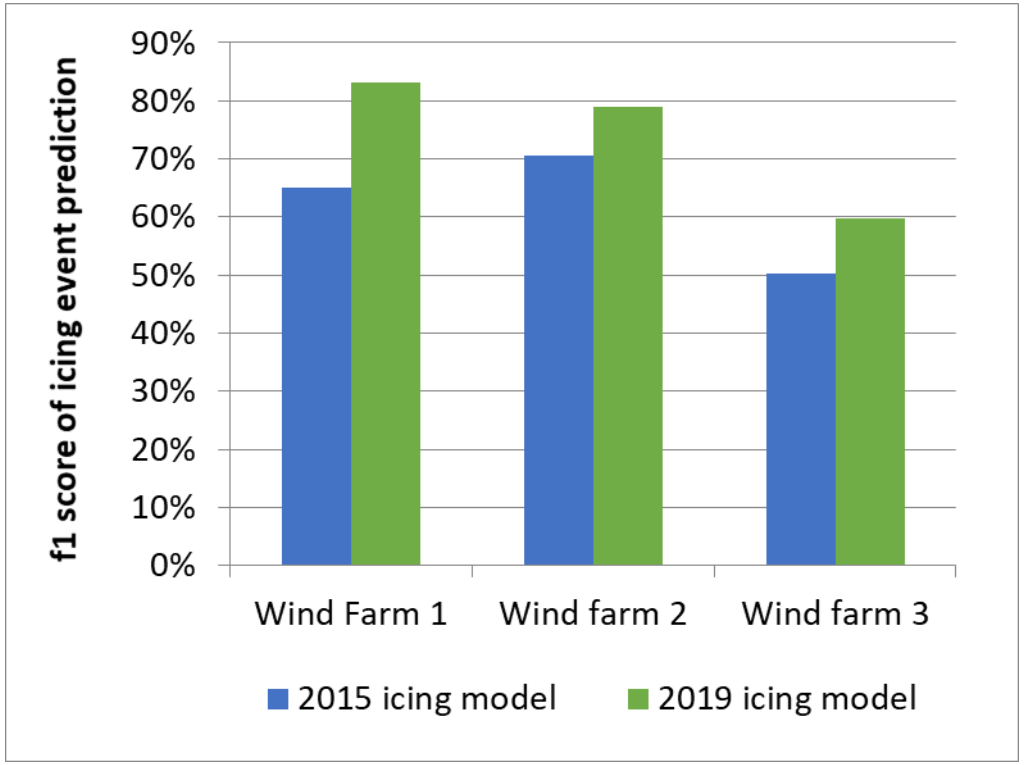
Results – prediction of icing events

Actual icing \ Forecast icing	no	yes
no	True Negative	False Positive
yes	False Negative	True Positive

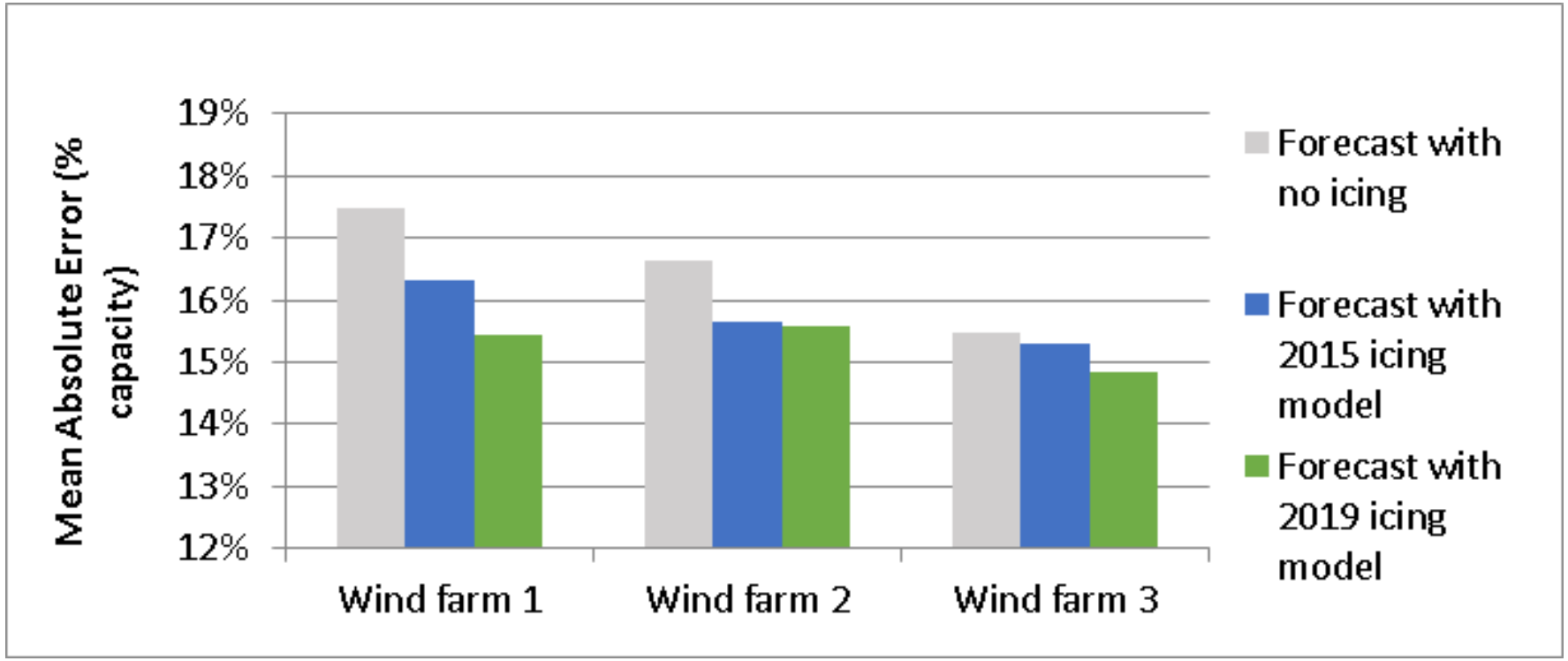
$$precision = \frac{TP}{TP + FP}$$

$$recall = \frac{TP}{TP + FN}$$

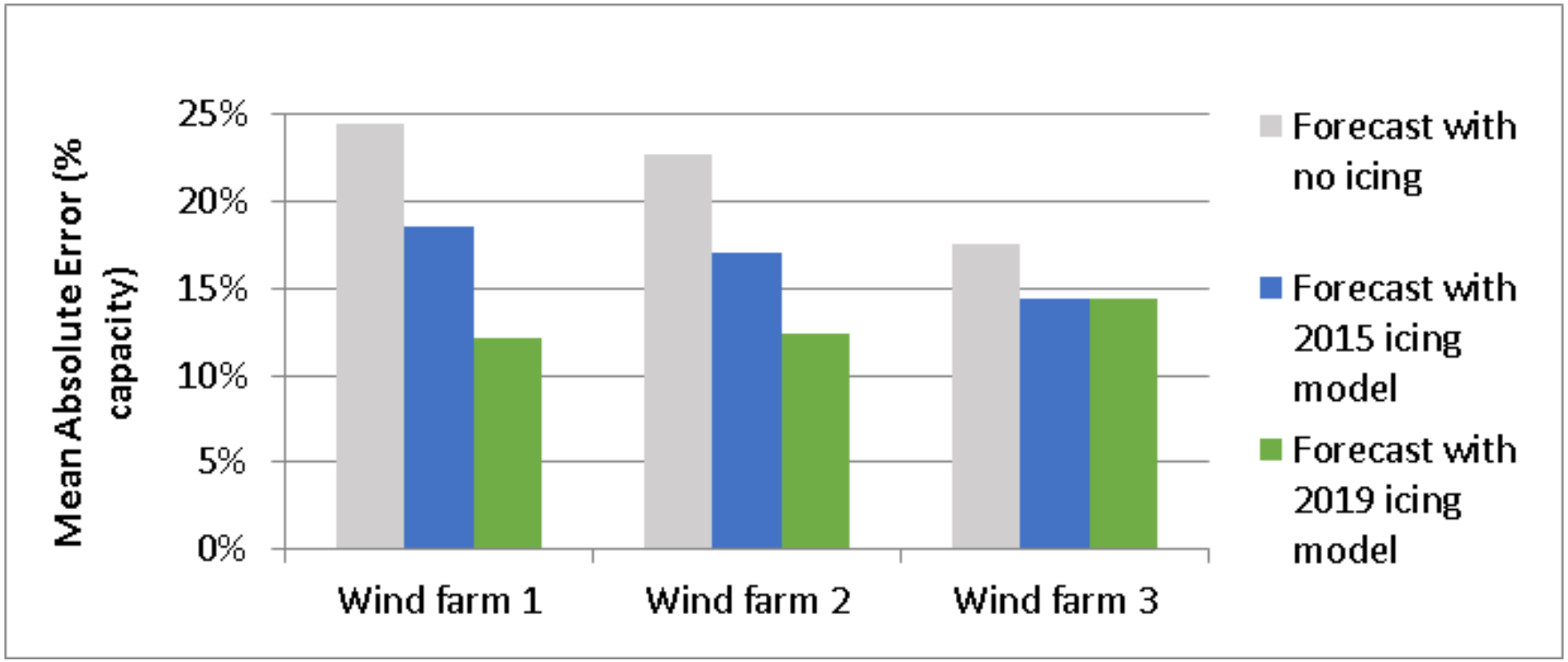
$$f1 = 2 \times \frac{precision \times recall}{precision + recall}$$



Results – Day Ahead Forecast for Whole Winter

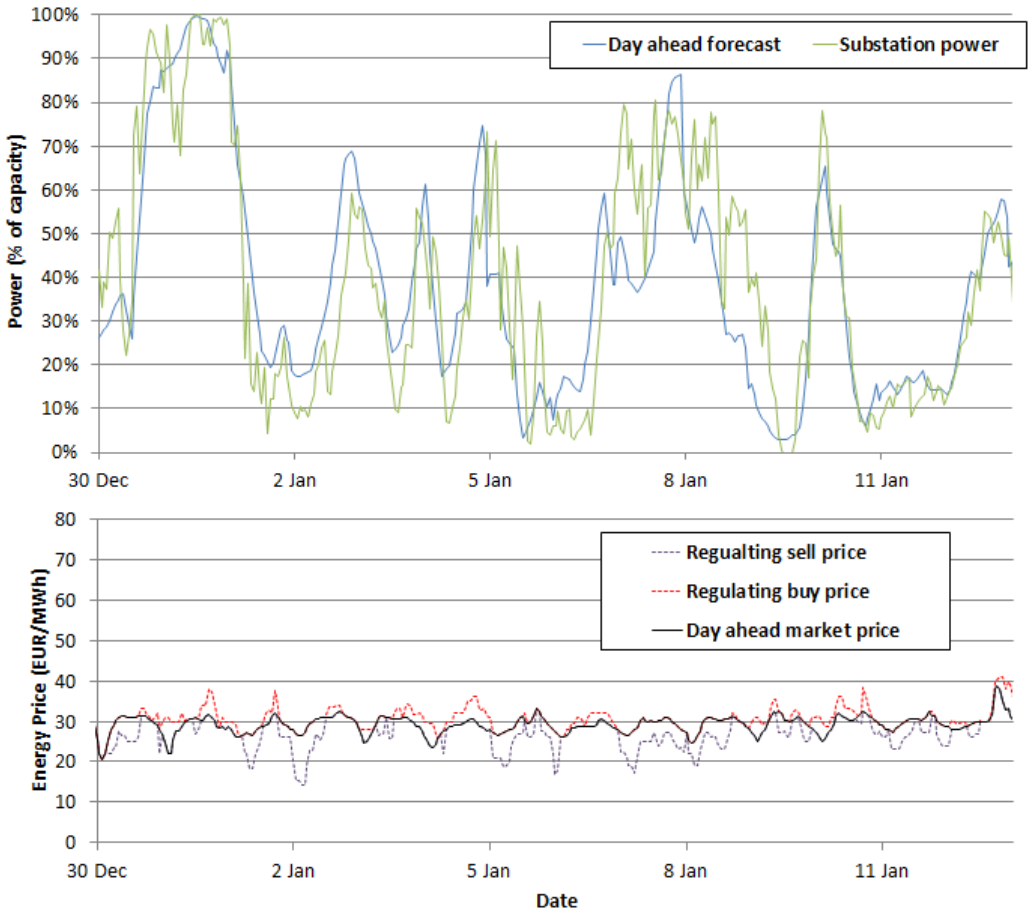


Results – Day Ahead Forecast for Iciest Month



The Nordic/Baltic day-ahead market (Elspot)

- 12:00 CET daily trade
- Hour by hour order of the next day
- Scheduled energy sold at Elspot day-ahead price
- Shortfall bought at regulation buy price
- Excess sold at regulation sell price



- For 30MW wind farm over one winter:
- Forecast (no ice) benefit ~ 65,000 EUR
- **Icing forecast benefit ~ 5,500 EUR**

Summary

- Machine learning model for icing adds significant value to power forecasts in cold climate
  - Successful in varying levels of icing
  - Reduces winter MAE by up to 0.9% capacity compared to older model
  - Reduces icy month MAE by over 6% capacity compared to older model

- Scope for model improvement
  - More/better input data (met. forecasts, feedback data)
  - Thawing/ice throw
  - Probabilistic forecast model

- Forecast accuracy improvement = increased revenue, informed operations, improved grid management

Thank you

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Umeå

	Monday				Tuesday								Wednesday								Thursday							
	1200	1500	1800	2100	0000	0300	0600	0900	1200	1500	1800	2100	0000	0300	0600	0900	1200	1500	1800	2100	0000	0300	0600	0900	1200	1500	1800	210
Winds (m/s):	12	8	6	5	4	4	4	4	6	5	4	4	3	3	3	2	4	4	4	6	8	9	9	8	5	4	3	3
WindDirection:	↘	↘	↘	↘	↘	↘	↓	↓	↓	↓	↓	↘	↘	↘	→	→	↗	↗	↗	↑	↑	↑	↗	↗	↗	↗	↗	↗
Temperature (°C):	-12	-12	-14	-17	-18	-19	-21	-22	-19	-19	-21	-23	-25	-25	-25	-19	-13	-11	-11	-7	-4	-3	-6	-7	-5	-6	-7	-8
Chance of rain (%):	75	62	29	18	7	16	16	23	20	21	17	19	10	11	10	9	6	7	10	41	63	69	61	48	21	17	21	18

SAFER, SMARTER, GREENER

DNV GL offers end to end services throughout the entire wind and solar project life cycle

YEAR -5

YEAR 25+

FEASIBILITY

- Mesoscale wind and solar resource mapping
- Site procurement
- Virtual meteorological data (resource compass)
- Icing assessments
- Measurement campaign specification
- Preliminary energy assessment

DEVELOPMENT

- Resource Panorama (online data management)
- Layout design and optimisation
- Pre-construction wind and solar energy assessments
- CFD wind flow modelling
- Site meteorological conditions assessment
- Power performance measurements

OPERATION

- Short-term forecasting
- SCADA based condition monitoring
- Asset monitoring and reporting
- WindGEMINI
- Operational wind and solar energy assessments
- Extension analysis

Previous icing model - Results