From icing loss to production loss -

a comprehensive comparison of today´s tools

(in Sweden)

Daniel Lindholm, Henrik Sundgaard Pedersen,
Wiebke Langereder

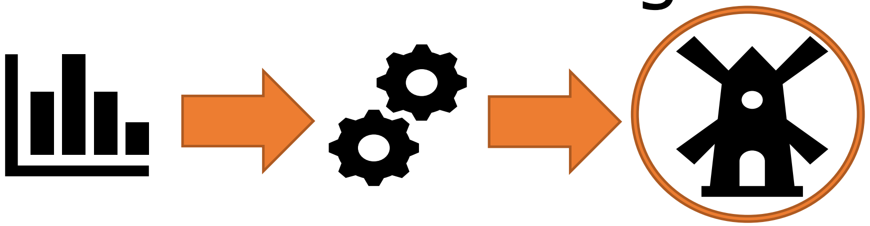
02-02-2018

EMD International A/S
www.emd.dk

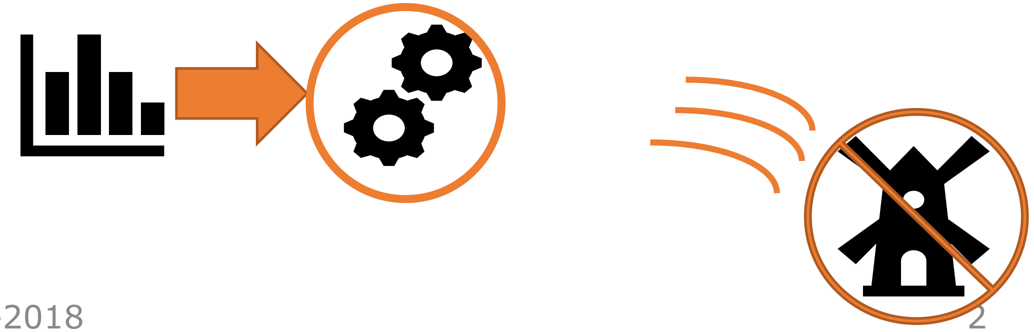
Background

Purpose of presentation

- Most presentations focus on finding out which model describes the icing on a turbine in the best way



- This presentation focuses on the expected difference between the current available models



Available methods

In this presentation the following methods were observed:

- “Fiddle factor” estimate
- IEA icing classification
- Kjeller Vindteknikks icing map
- WIceAtlas map
- DNV/GL Ice map.

Model description

“Fiddle factor”

- Basically uses a factor on the observed icing
- Examples have been seen varying from 0,25-0,5.
- Could possibly be related to turbine technology

Challenges

- Result highly dependent on the factor chosen
- “Based on experience” is a rather vague argument

Model description

IEA icing classification

- Defined both as meteorological and instrumental icing
- A site can end up in two separate Ice classes
- Production loss assumed Long term classified

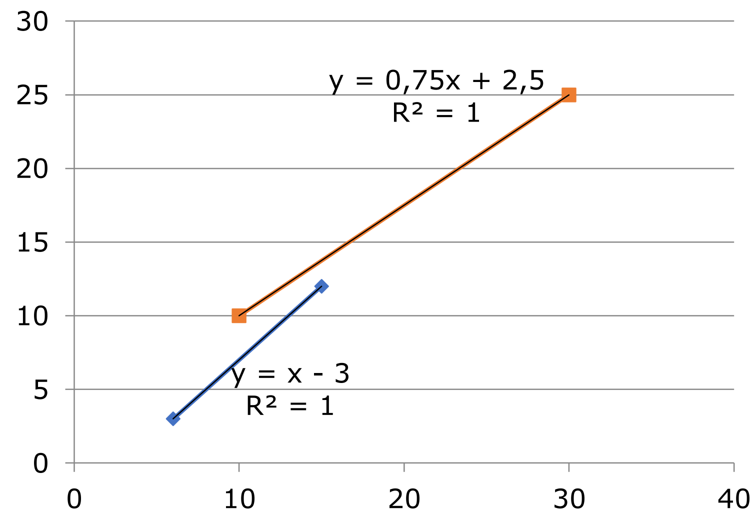
IEA Ice class	Meteorological icing	Instrumental icing	Production loss
	% of year	% of year	% of annual production
5	>10	>20	> 20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0 - 0.5

Challenges

Using IEA icing classification

- Specifies that unheated sensors should be used
- Overlapping Classes and "unusable" range of expected losses

Instrumental icing	Production loss
% of year	% of annual production
>20	> 20
10-30	10-25
6-15	3-12
1-9	0.5-5
<1.5	0 - 0.5



EMD International A/S
www.emd.dk

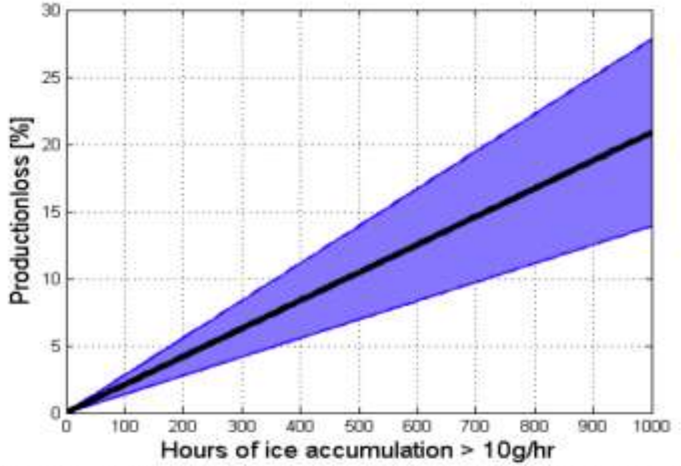
Model description

Kjeller Vindteknikks icing map

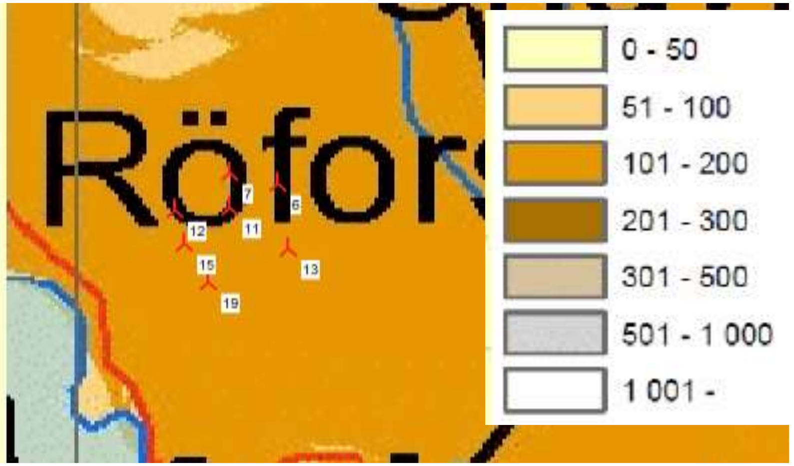
- Presents icing as number of icing hours per year (dM>10g/hr) 100m above ground level.
- Long term corrected (2000-2011)

Challenges

- Low Resolution and inability to capture local "coldspots"
- Estimates presented in a range



g. 6. Estimated range for production loss. Lower boundary is given by (2). pper boundary is given as twice the lower boundary.



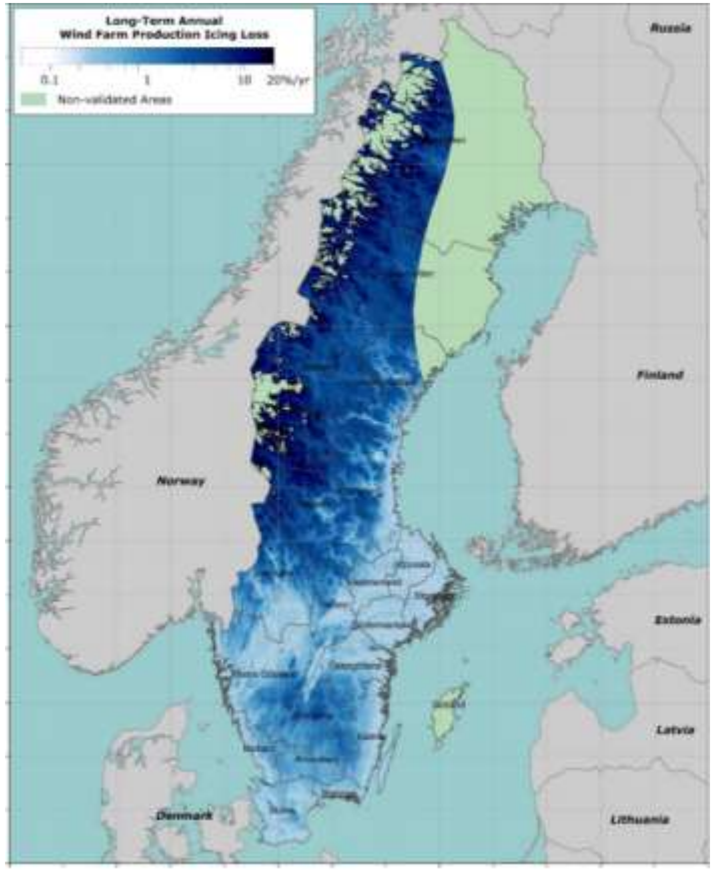
Model description

DNV/GL map

- Based on production data and the relationship between hub height elevation and ice loss
- Inter annual variability taken into account

Challenges

- Questions related to the second trend (not implemented in the current ice map)
- Annoying color gradient



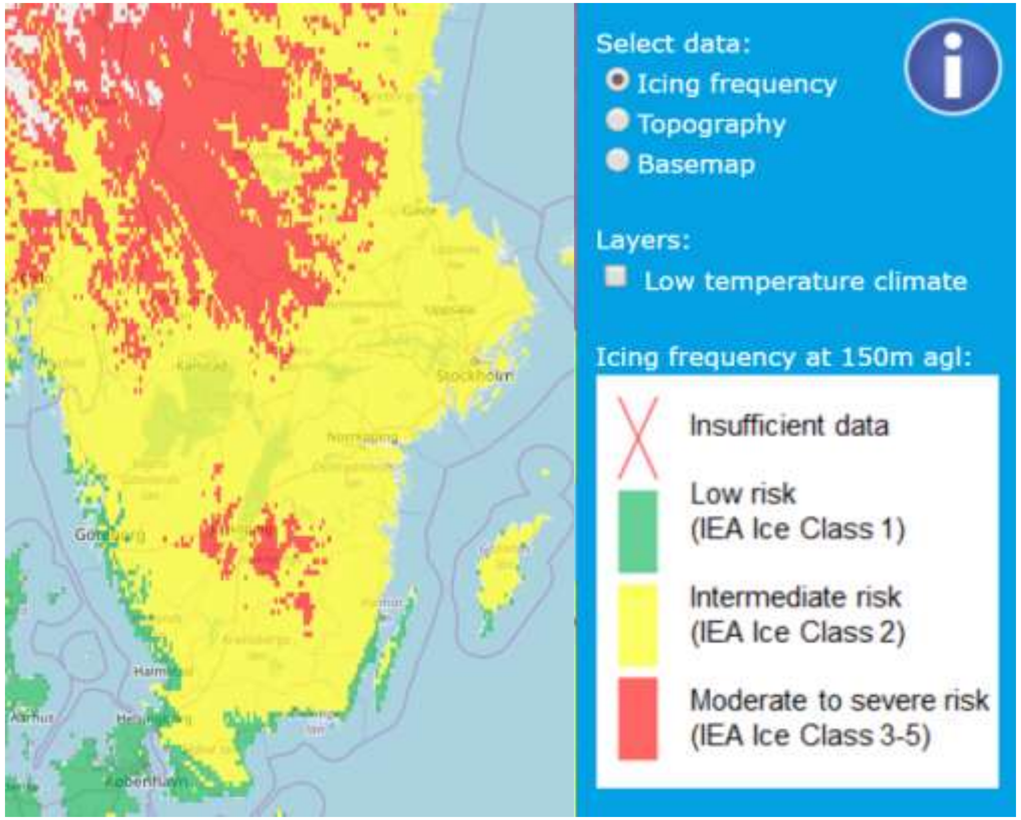
Model description

WIceAtlas map

- Shows icing frequency at 150m agl
- Presents results as IEA ice class

Challenges

- Hard (as in not really possible) to convert to a usable single value



Limitations

Goal of the analysis

- Comparison of the different methods on the same location
- Create a basis for expected differences and uncertainties in pre construction situations using observed models

Data input used for evaluation

- Only masts between 85-100m used for evaluation
- Only Thies shaft heated anemometers used for evaluation

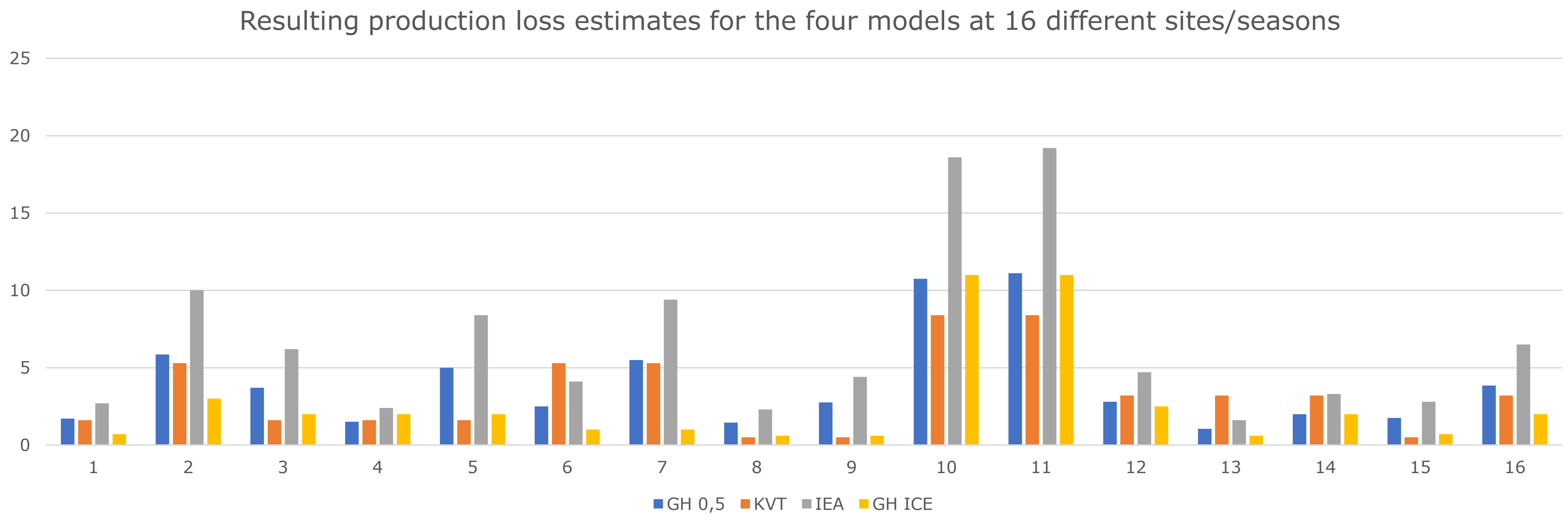
Methodology

Assumptions and methodology

- Flagging system based on ΔV between fully heated and shaft heated anemometer as well as instrumental stand-still.
- Period assumed to start 30 minutes before and after each flagged period
- Only one winter season is taken into account
- Multiple winters are split and treated separately
- Mean value from Kjeller Vindteknikk map ranges used
- Single value based on linear relationship used for IEA maps
- “Fiddle factor” of 0,5 used for presentation
- Visual inspection of color coding for GH&DNV ice map
- Long term corrected with EMD Icing index

Results

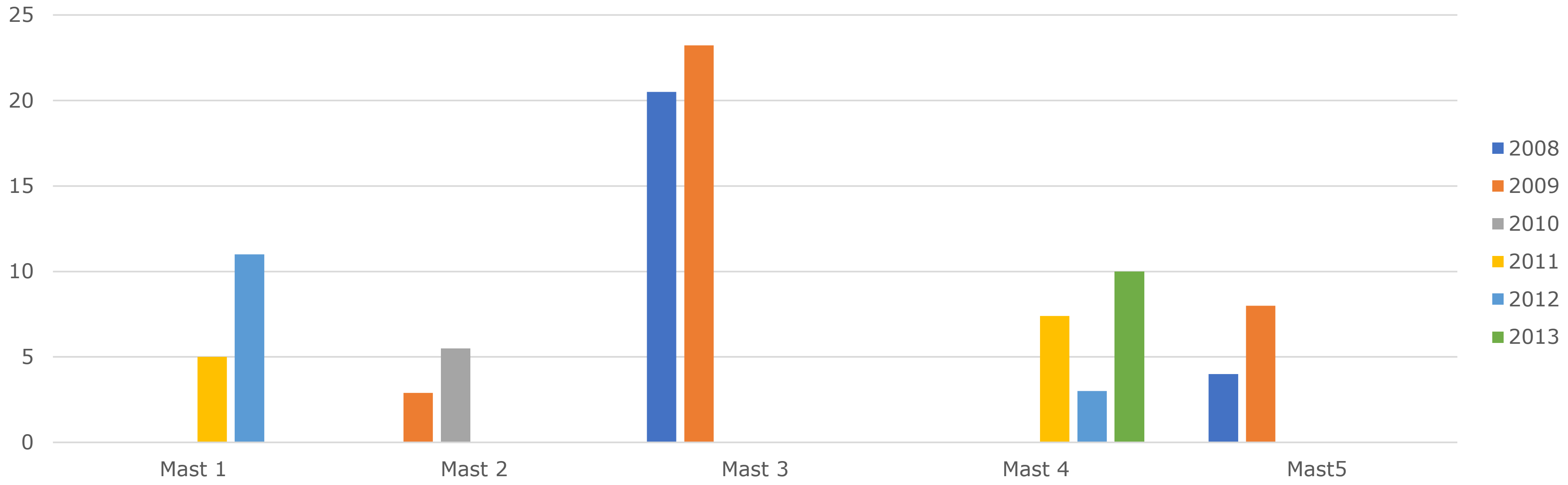
Difference of expected production loss



EMD International A/S
www.emd.dk

Results

Inter annual difference in instrumental icing

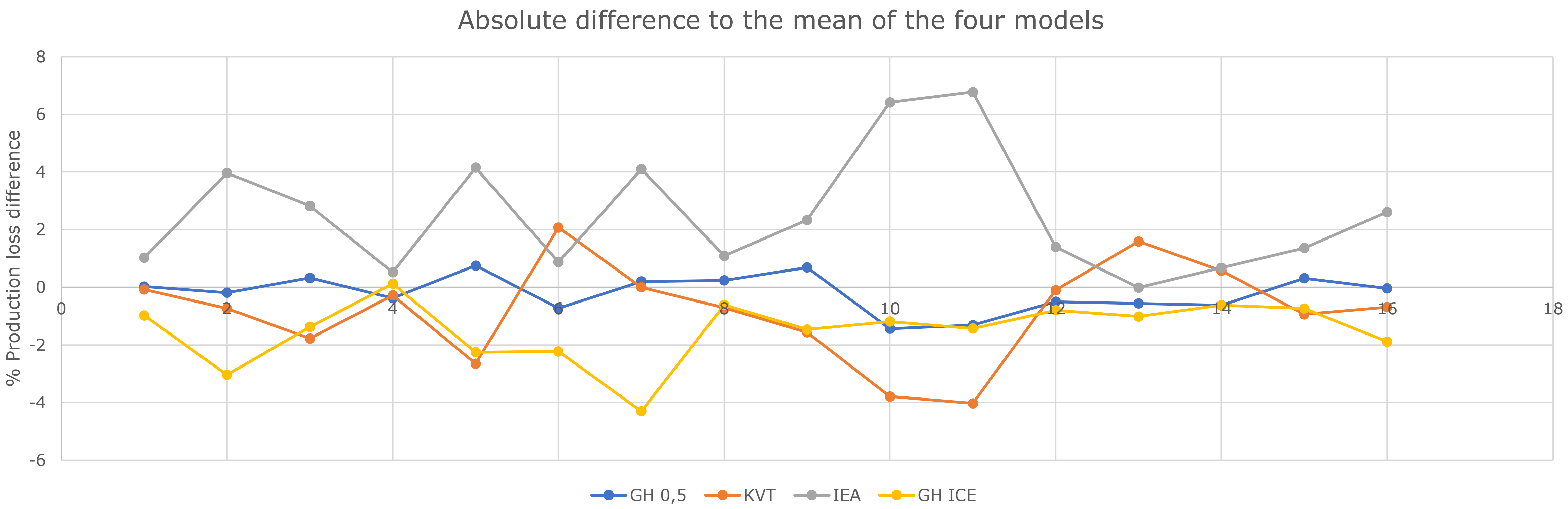


- Long term correction of instrumental icing is necessary!

EMD International A/S
www.emd.dk

Results

Difference of expected production loss



EMD International A/S
www.emd.dk

Wrap-up

What can be learned

- Some spread can be seen, but the absolute difference is overall within acceptable uncertainty levels
- Using a mean value of all methods is a possible approach
- Having one year of measurement as a basis for a icing loss evaluation increases uncertainty due to inter annual variability

Thank you for listening!

List of sources

- [1] "Icing Map of Sweden," Kjeller Vindtekknik, http://www.vindteknikk.com/_extension/media/83/orig/KVT_OB_2012_R076_Icingmap_Sweden.pdf, 2012.
- [2] WIceAtlas (VTT) More or less global coverage; http://virtual.vtt.fi/virtual/wiceatla/
- [3] DNV-GL – Sweden… 17_WindEurope2016-Icinglosses-Whatcanwelearnfromproductionandmeteorologicaldata.pdf
- [4] IEA, 13. Wind Energy Projects in Cold Climate, Expert Group Study on Recommended Practice, 2017.
- [5] Rene Cattin, on behalf of IEA Task 19: Blind Icing map Validation, Winterwind 2015, http://winterwind.se/wp-content/uploads/2015/08/7_2_09_Cattin_IEA_Task_19_-_Blind_icing_map_validation_Pub_v2-6.pdf
- [6] Rene Cattin, on behalf of IEA Task 19: Validation of the IEA Task 19 Ice Classification, Winterwind 2016, http://winterwind.se/wp-content/uploads/2016/02/3_3_3_Cattin_Validation_of_the_IEA_Task_19_ice_site_classification.pdf
- [7] Ø. Byrkjedal, Estimating Wind Power Production Loss due to Icing, Kjeller Vindtekknik, IWAIS XII, Andermatt, 2009
- [8] T.Duncan et al., GH: Understanding Icing Loasses and Risk of Ice Thorw at Operating Wind Farms, Winterwind 2008, http://www.winterwind.se/2008/presentationer/08_Landberg_Winterwind_2008.pdf