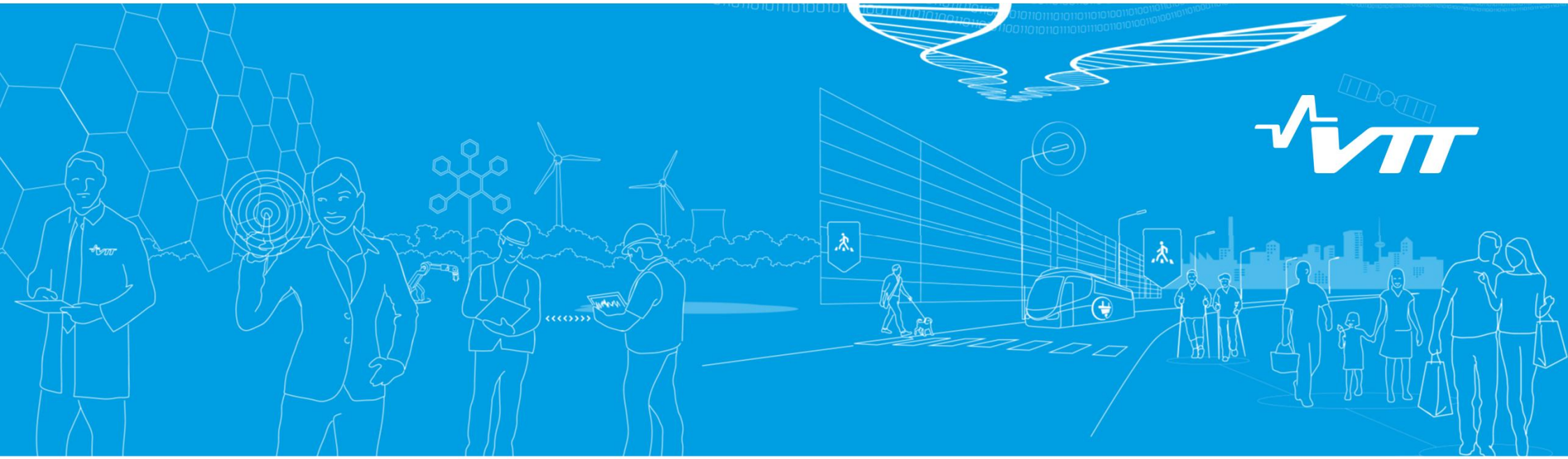

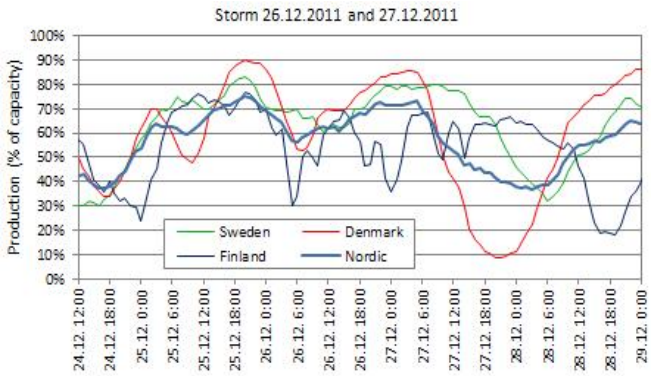

Nordic wind power variability, forecast errors and impact on balancing needs

Icewind workshop 3rd December 2014, WP4

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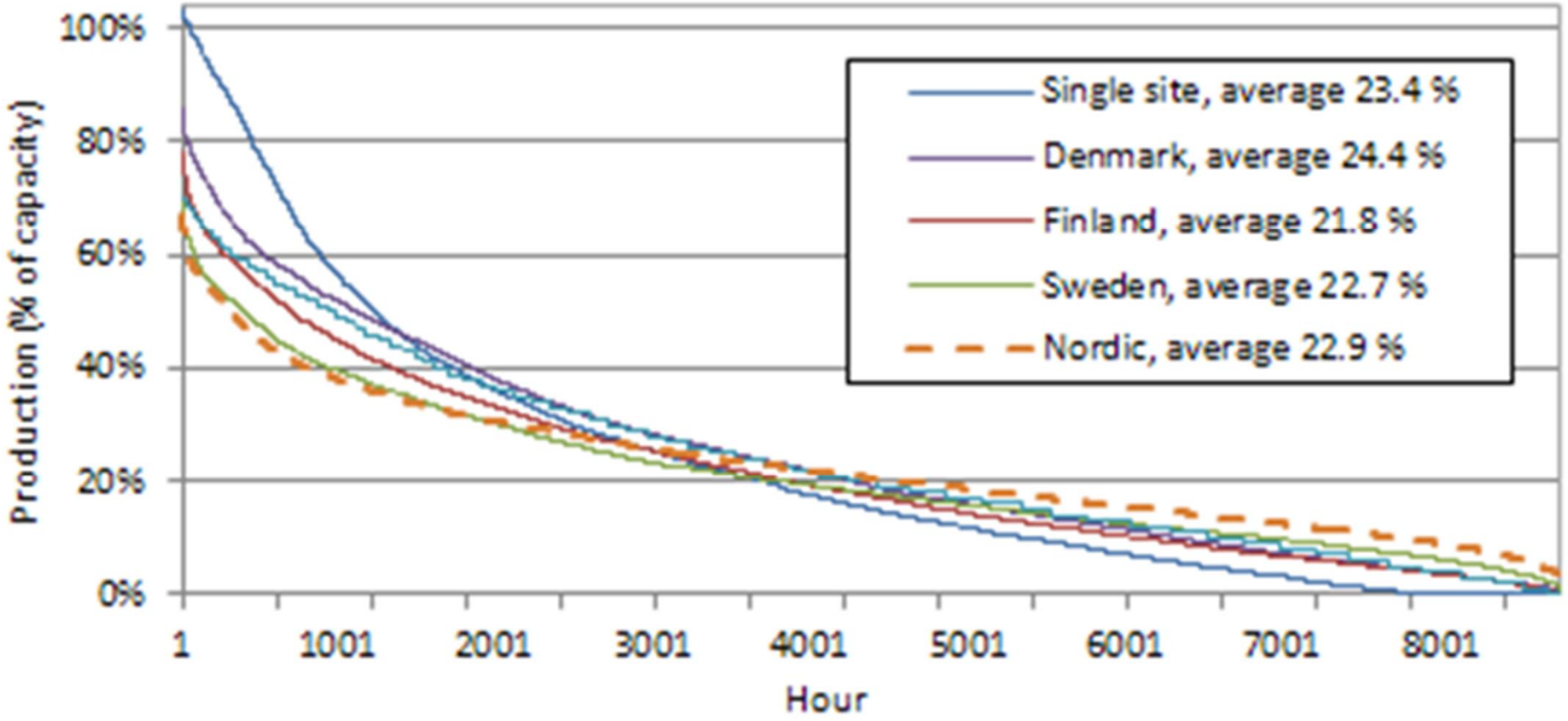
VTT Technical Research Centre of Finland

Contents

- Variability of wind power in Nordic countries – smoothing impact
  - Holttinen, Hannele, Rissanen, Simo, Larsen, Xiaoli, Løvholm, Anne Line. 2013. Wind and load variability in the Nordic countries. VTT Technology: 96, Espoo, VTT, 98 p. + app. 33 p. http://www.vtt.fi/inf/pdf/technology/2013/T96.pdf
  - Holttinen, Hannele, Rissanen, Simo, Giebel, G., Larsen, X., Løvholm, A.-L., Berge, E.. 2012. Variability and smoothing effect of wind power production compared to load variability in the Nordic countries. WIW12, Lisbon, Portugal, 13 - 15 Nov. 2012
- Extreme case – storms, how often and wide area?
- Forecast accuracy and aggregation benefits
  - Holttinen, Hannele, Miettinen, Jari, J., & Sillanpää, Samuli. 2013. Wind power forecasting accuracy and uncertainty in Finland. VTT Technology: 95, Espoo, VTT, 60 p. + app. 8 p. http://www.vtt.fi/inf/pdf/technology/2013/T95.pdf
- Wind power impacts on balancing
  - Miettinen, Jari J, Holttinen, Hannele, Giebel, G. 2014. Nordic Wind Power Forecast Errors: Benefits of Aggregation and Impact to Balancing Market Volumes. WIW2014, Berlin, 11 - 13 Nov, 2014.
  - Miettinen, Jari J, Holttinen, Hannele. 2013. Prediction Errors and Balancing Costs in Finland Using Short Term Prediction for Different Geographical Areas. WIW2013, London, 22 - 24 Oct, 2013.

VARIABILITY ANALYSES

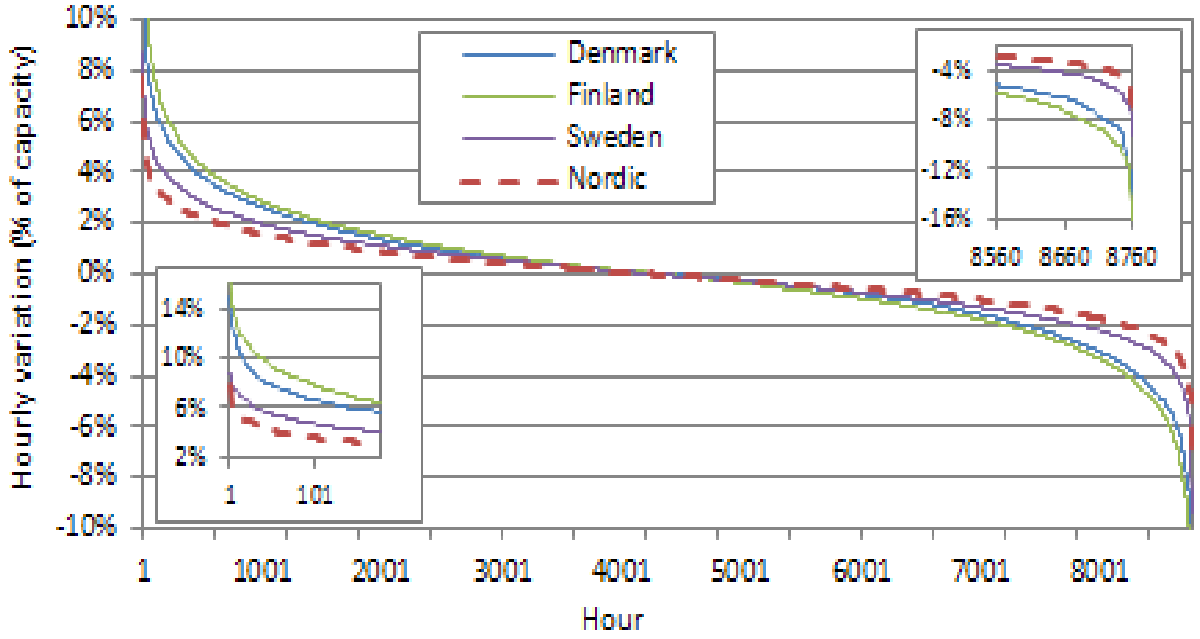
Smoothing effect– hourly time series of production

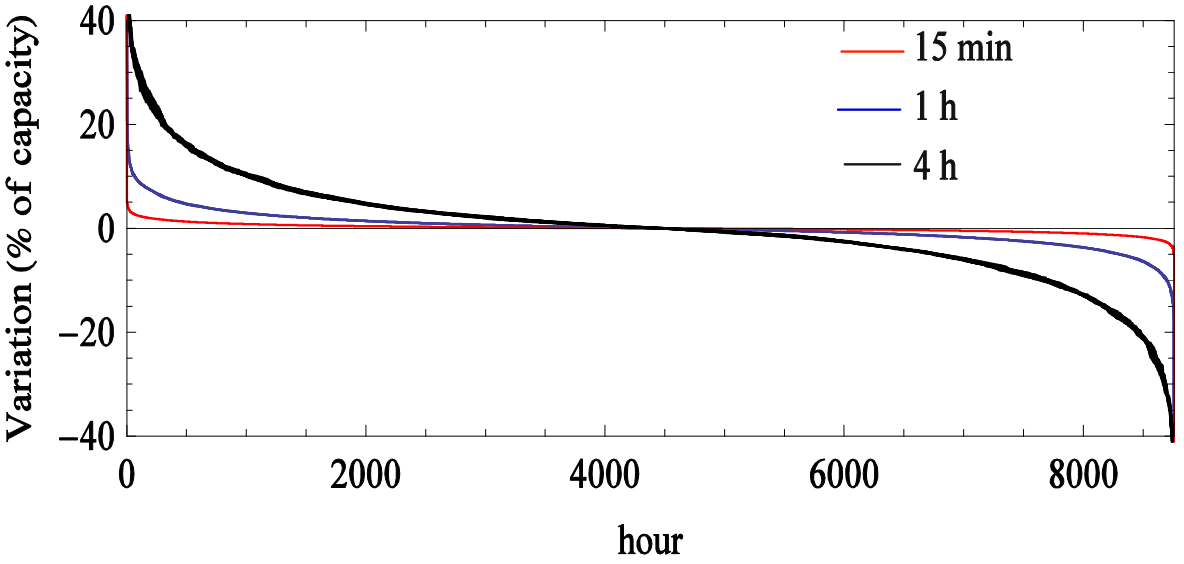


- Year 2010 data (low wind year). Nordic max 75 %, min 1 %
- Nordic data: SE = DK and FI, NO = 50 % of DK

Smoothing of variability

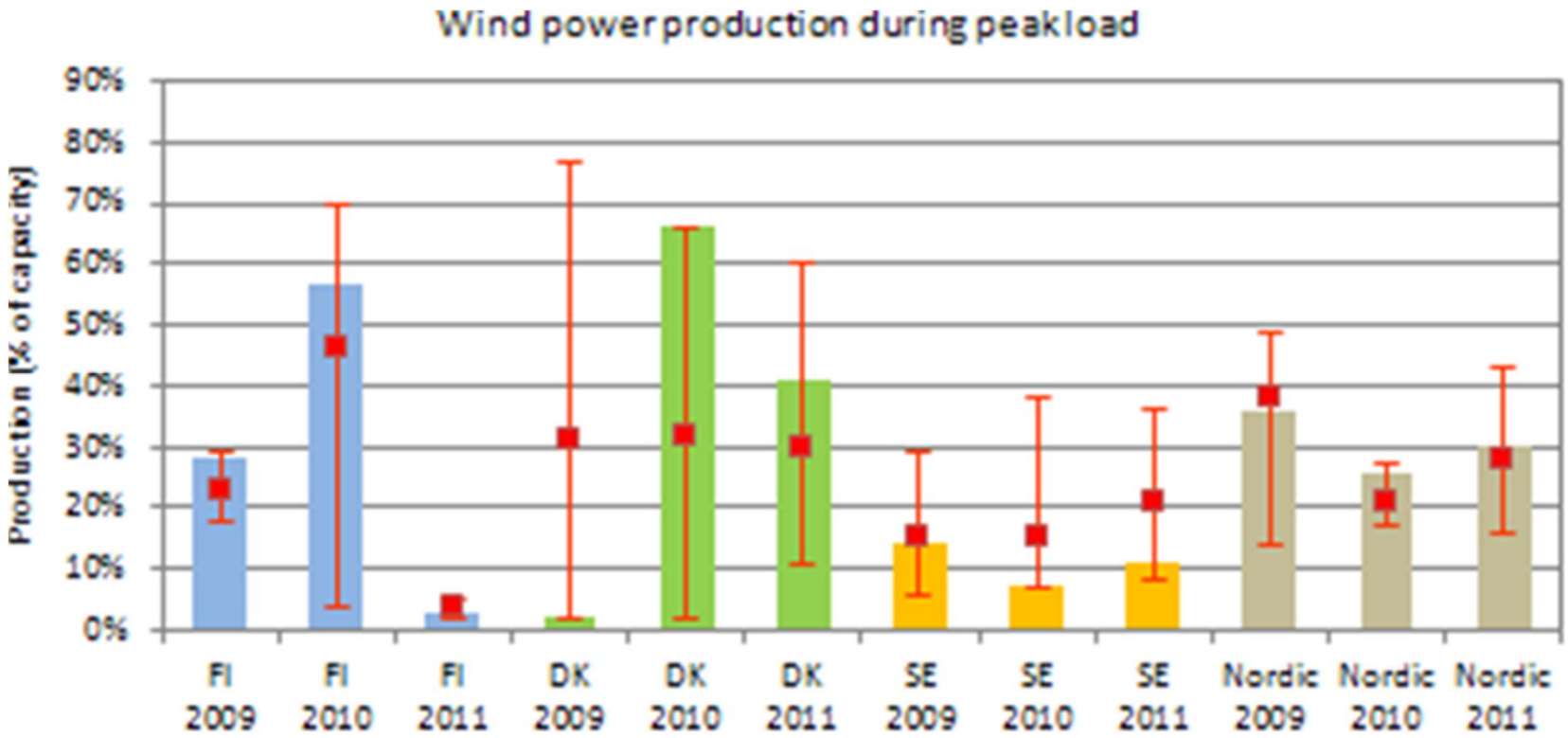
- Hourly variability ± 20 % Finland, ± 18 % Denmark, ± 10 % Sweden, ± 8 % Nordic
- 15 min variability about half of hourly variability
- 4 hour variability 2-3 larger than hourly variability





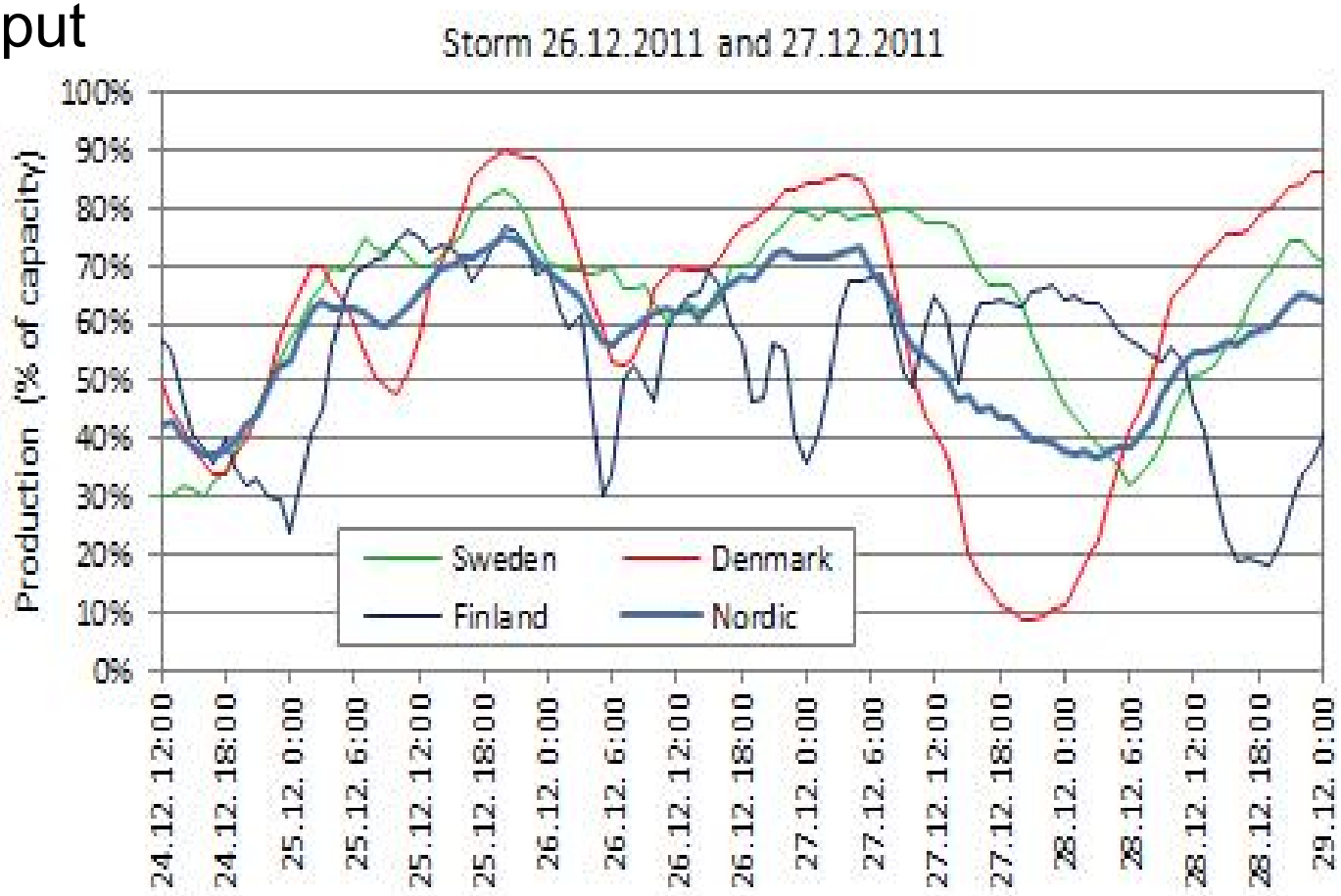
Production during peak load

- Minimum, maximum and average wind power production during 10 highest peaks are shown with red error bars
- Single country as low as 2%. Nordic: 25 %, 30 % and 35 %. During the 10 largest peaks per year, 15-50 %



Storms

- 3 years: largest event after Xmas 2011.
- Impact seen locally. Ramps less than 50 % of capacity in any country due to storm and no impact in the Nordic aggregated wind power output

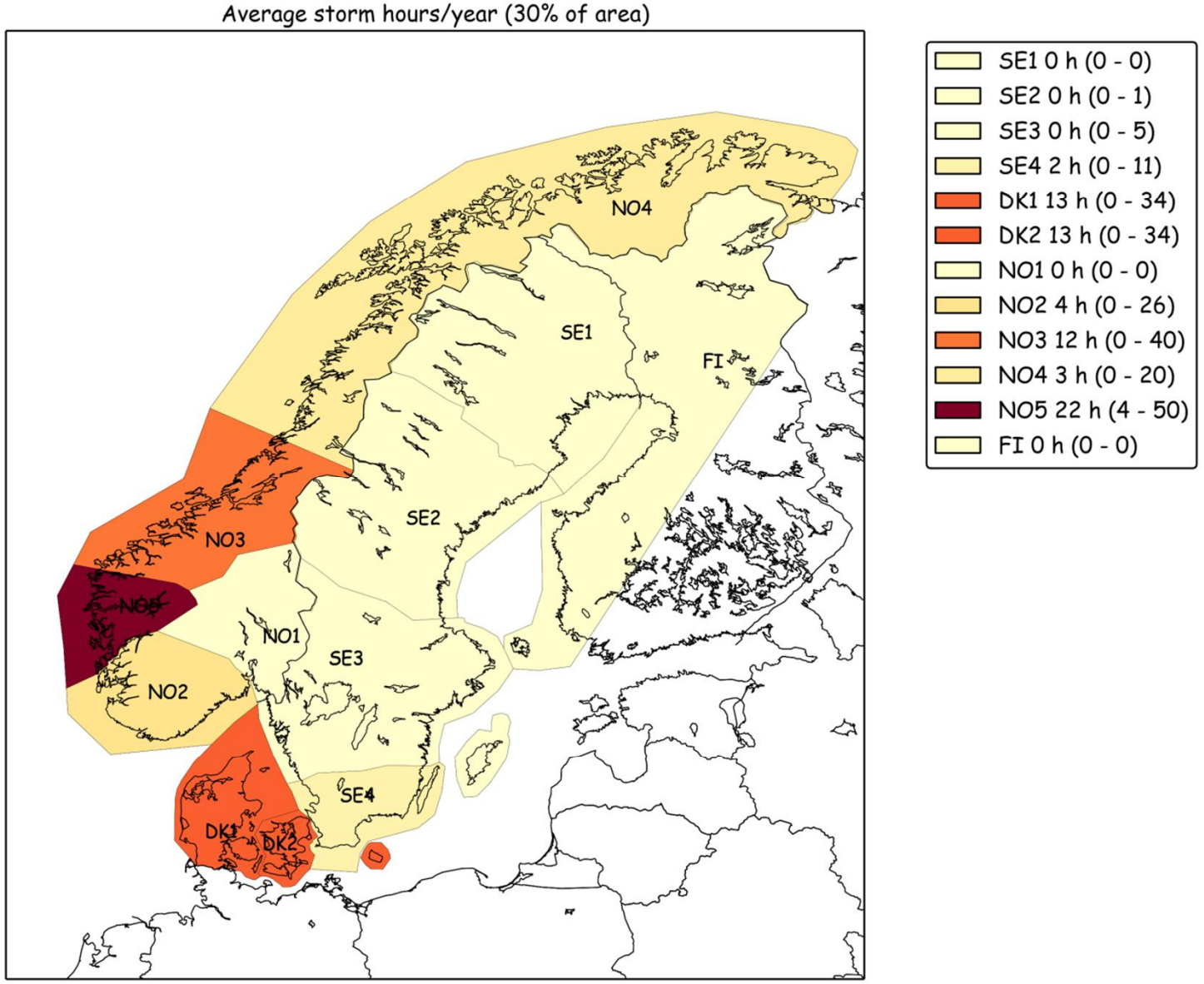


Storm analysis: 14 years of model data ~115 m.a.g.l

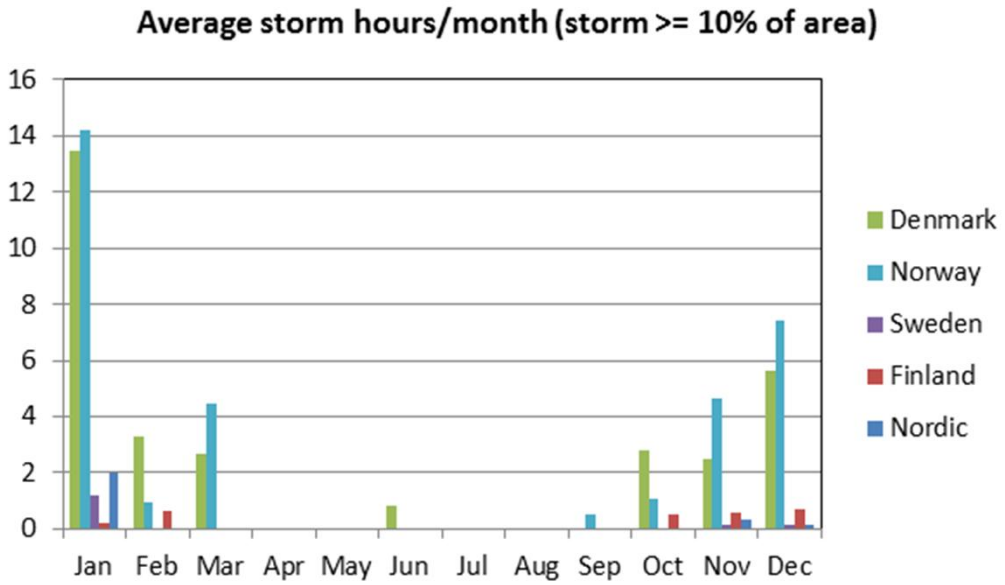
Area	gridpoints (4x4 km)	Number of land points	Offshore
SE1	7768	6890	11 %
SE2	9670	8483	12 %
SE3	12228	8561	30 %
SE4	3823	2421	37 %
DK1	4116	2094	49 %
DK2	1730	601	65 %
NO1	3454	3219	7 %
NO2	4722	3302	30 %
NO3	5777	3919	32 %
NO4	12398	6881	44 %
NO5	3026	1794	41 %
FI	13009	9872	24 %

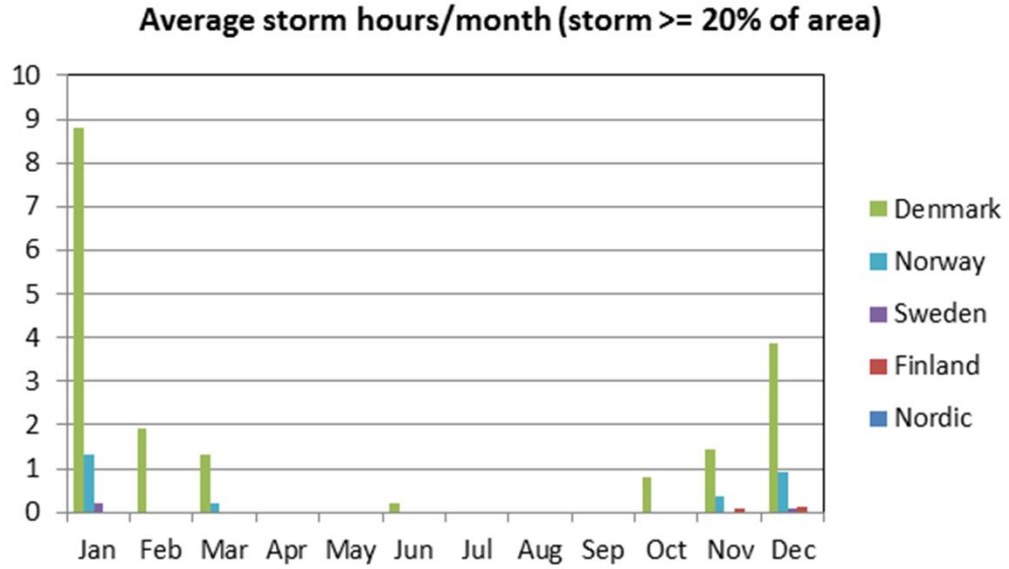
Areas divided as price areas of Nordic market. Offshore % in areas

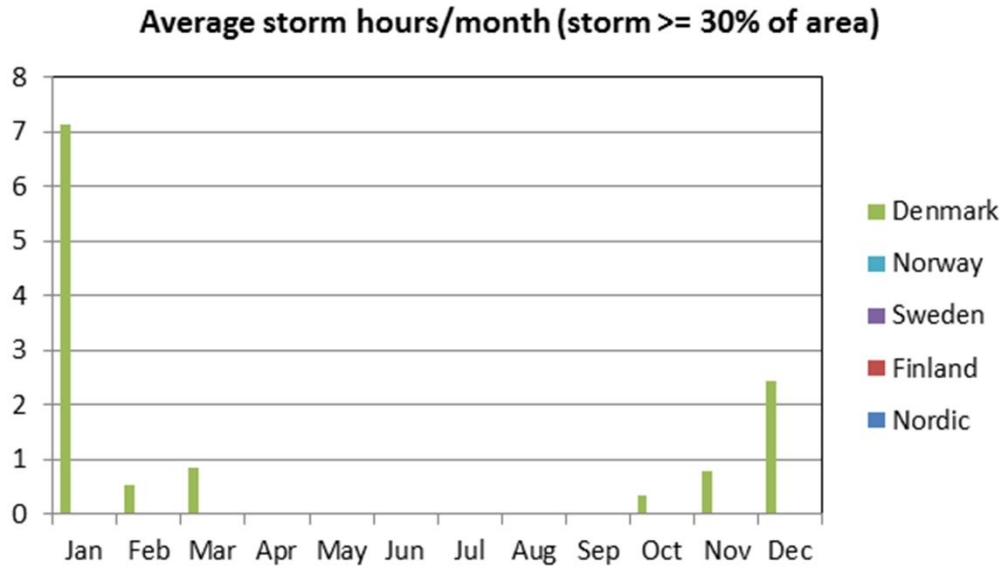
Storms > 30 % of area – locally in Norway and Sweden

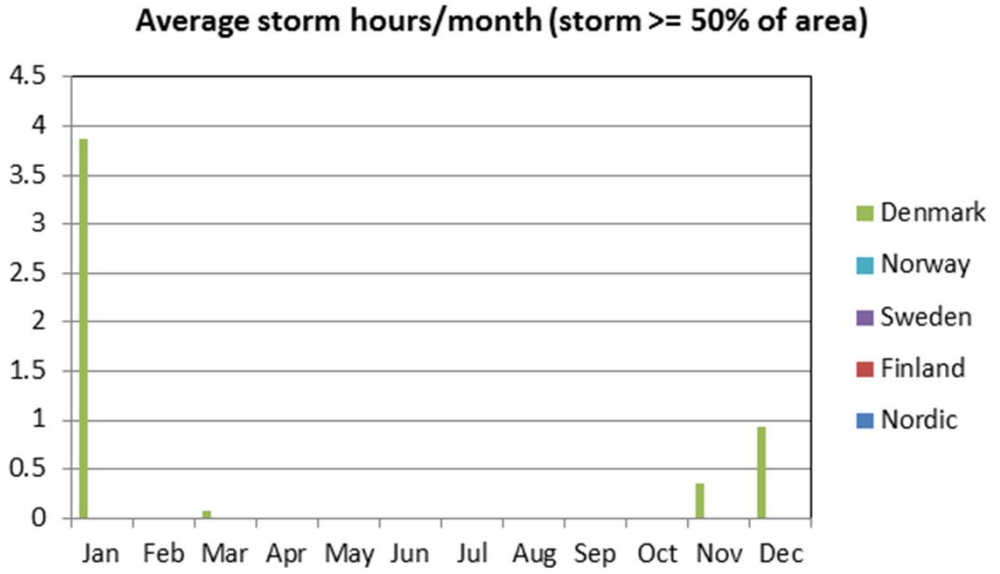


Storms > 30 % of country area - only in Denmark

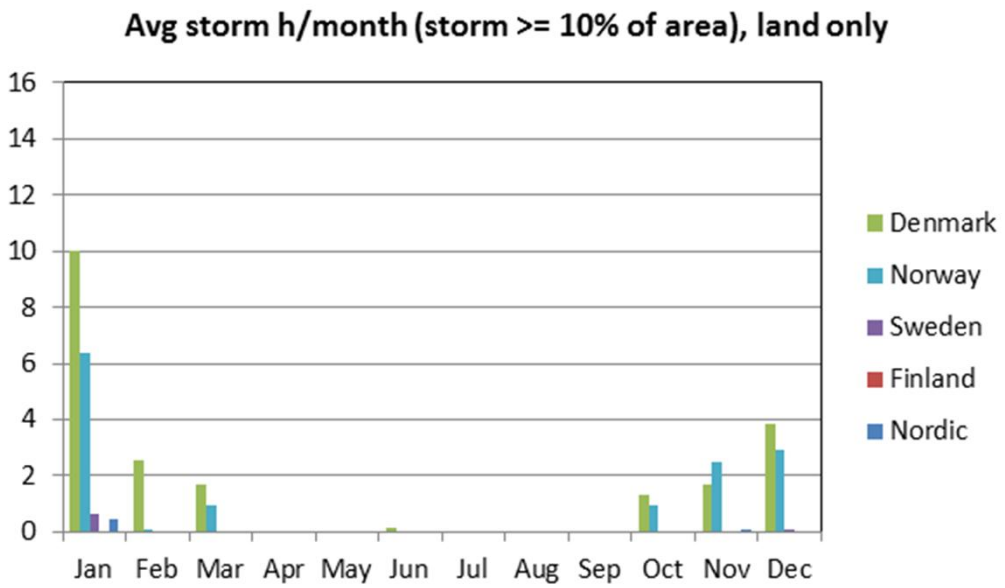


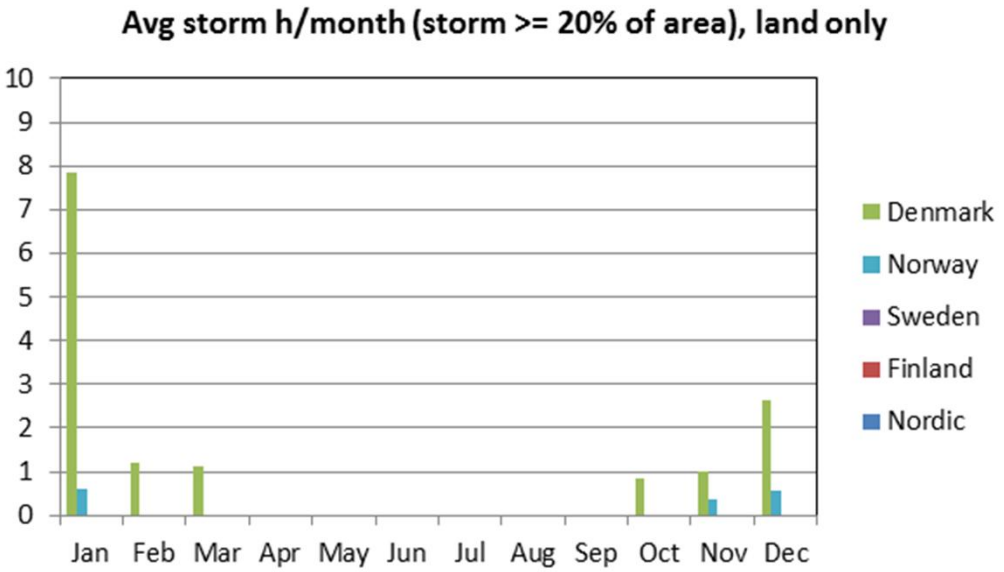


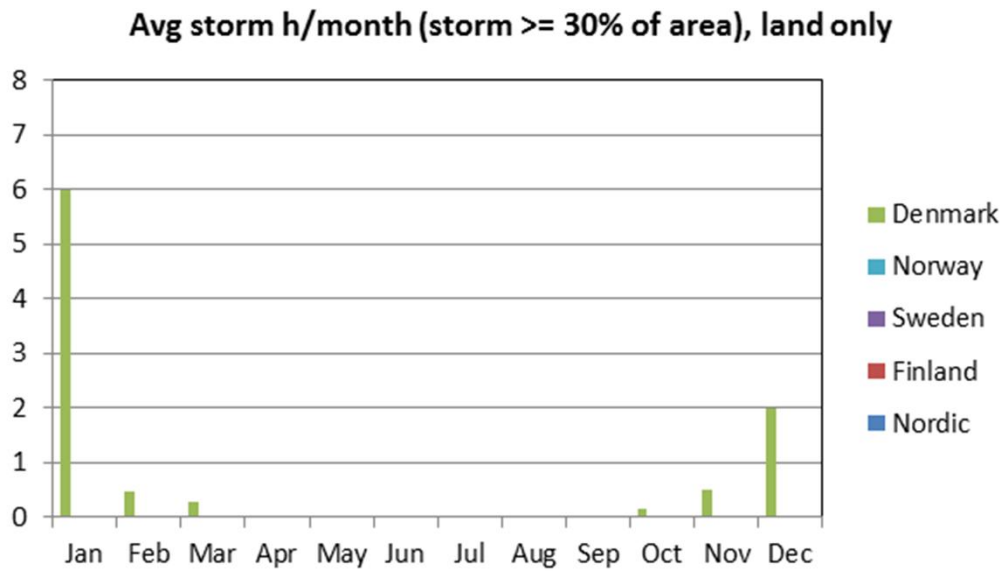


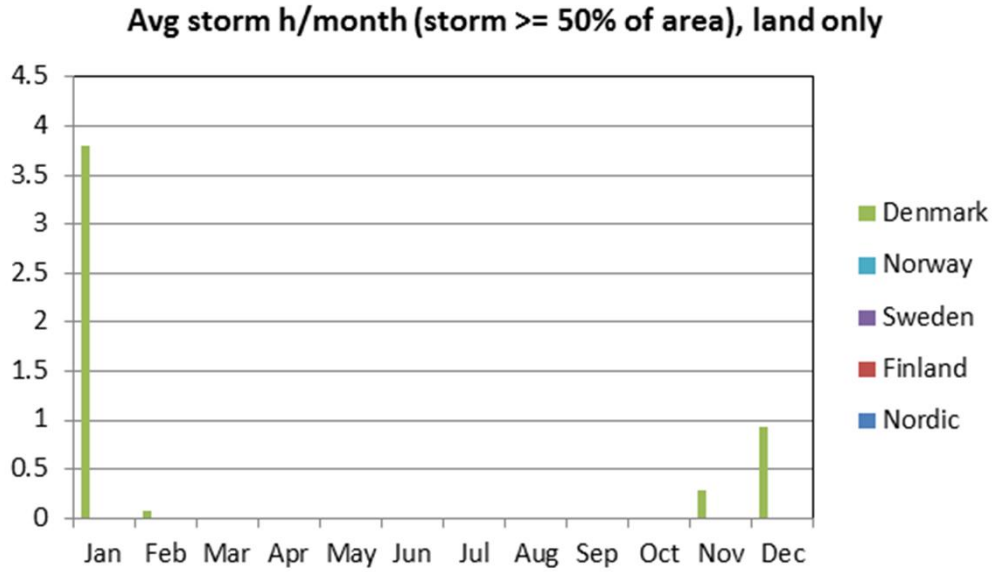


If only land-based wind power



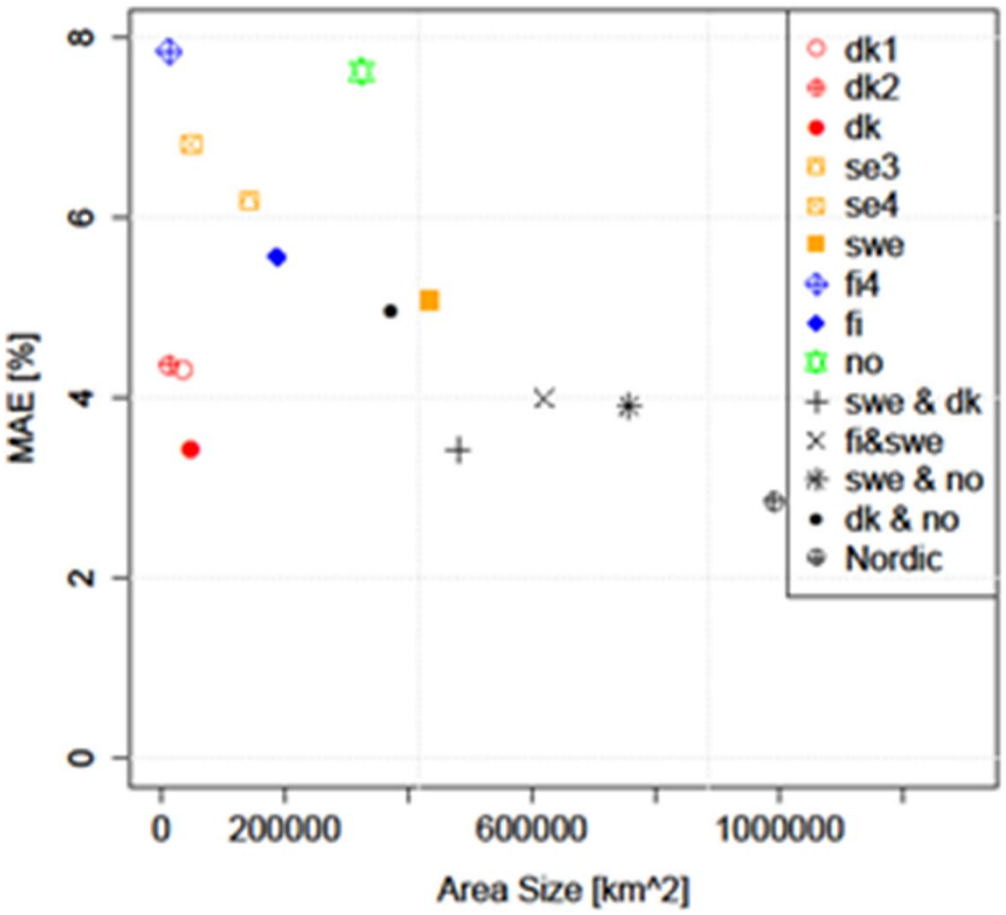


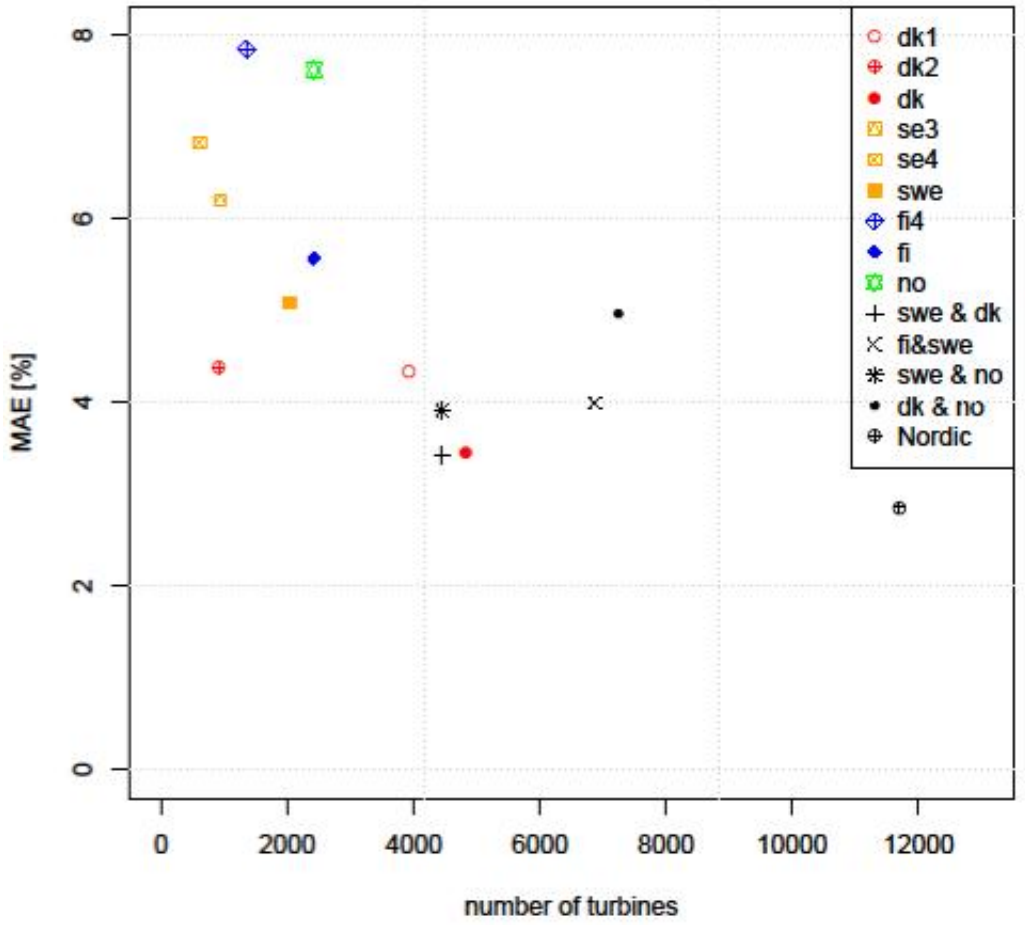




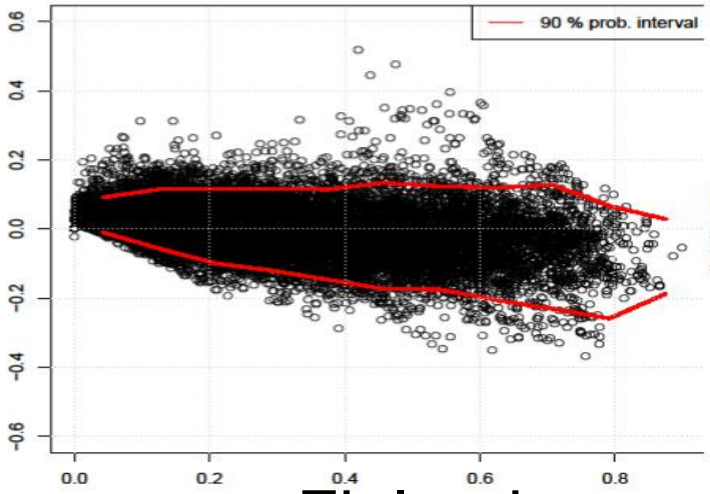
FORECAST ERROR ANALYSES

MAE on different sizes of areas and number of turbines

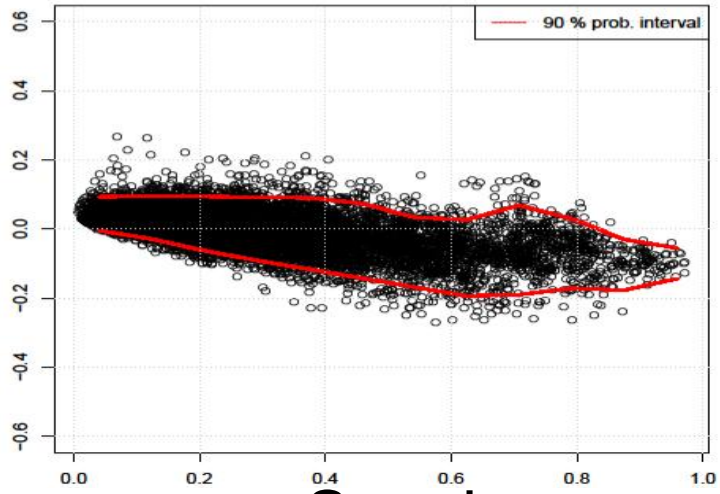




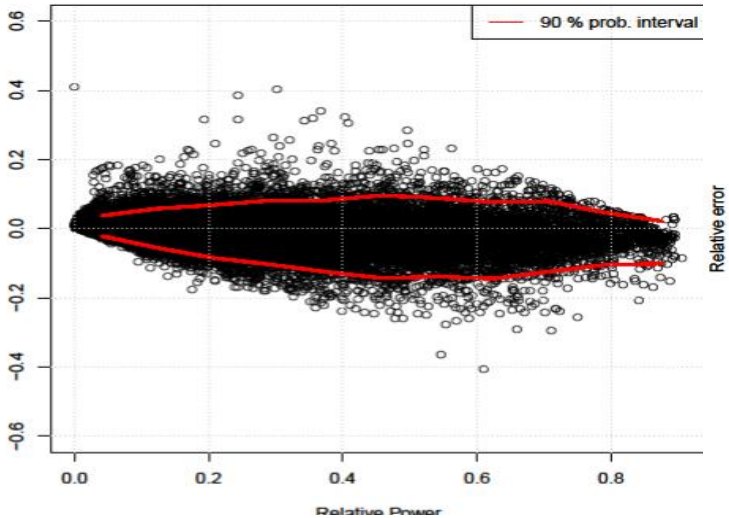
Forecast errors on different power levels in Finland, Sweden. Denmark and Nordic



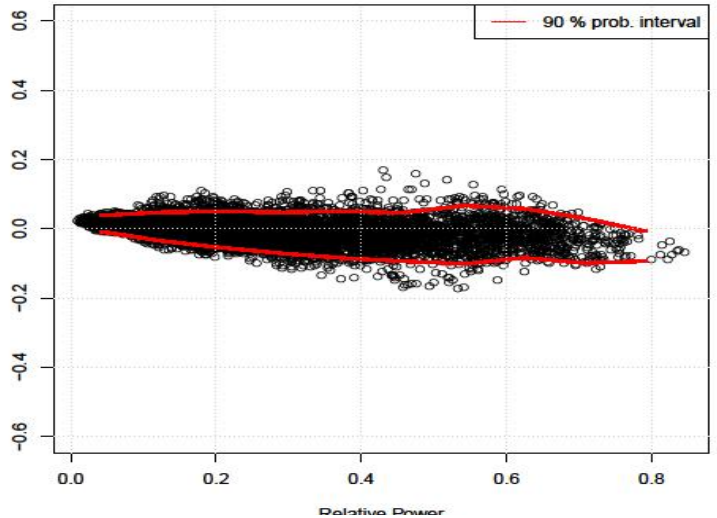
Finland



Sweden



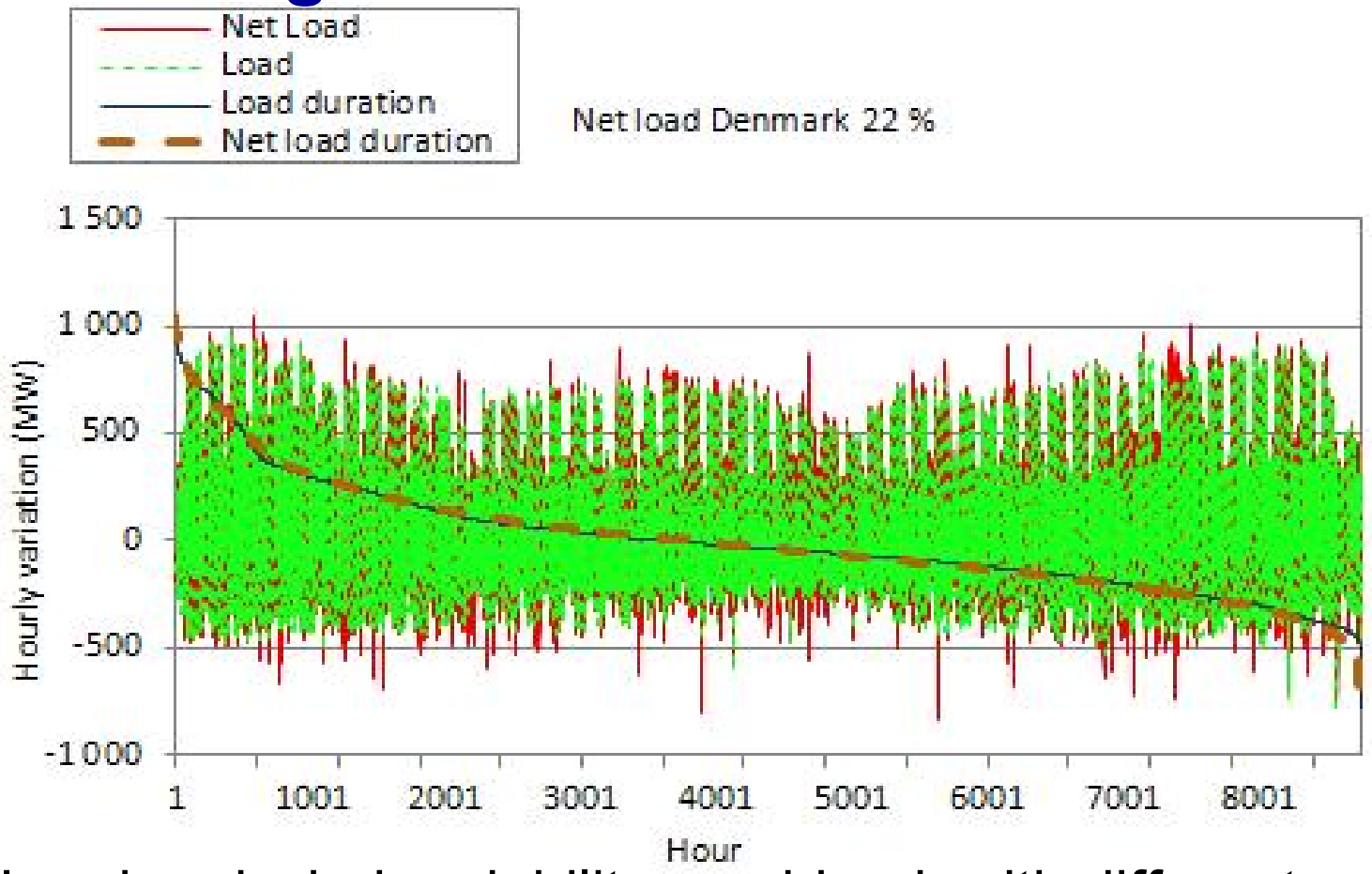
Denmark



Nordic

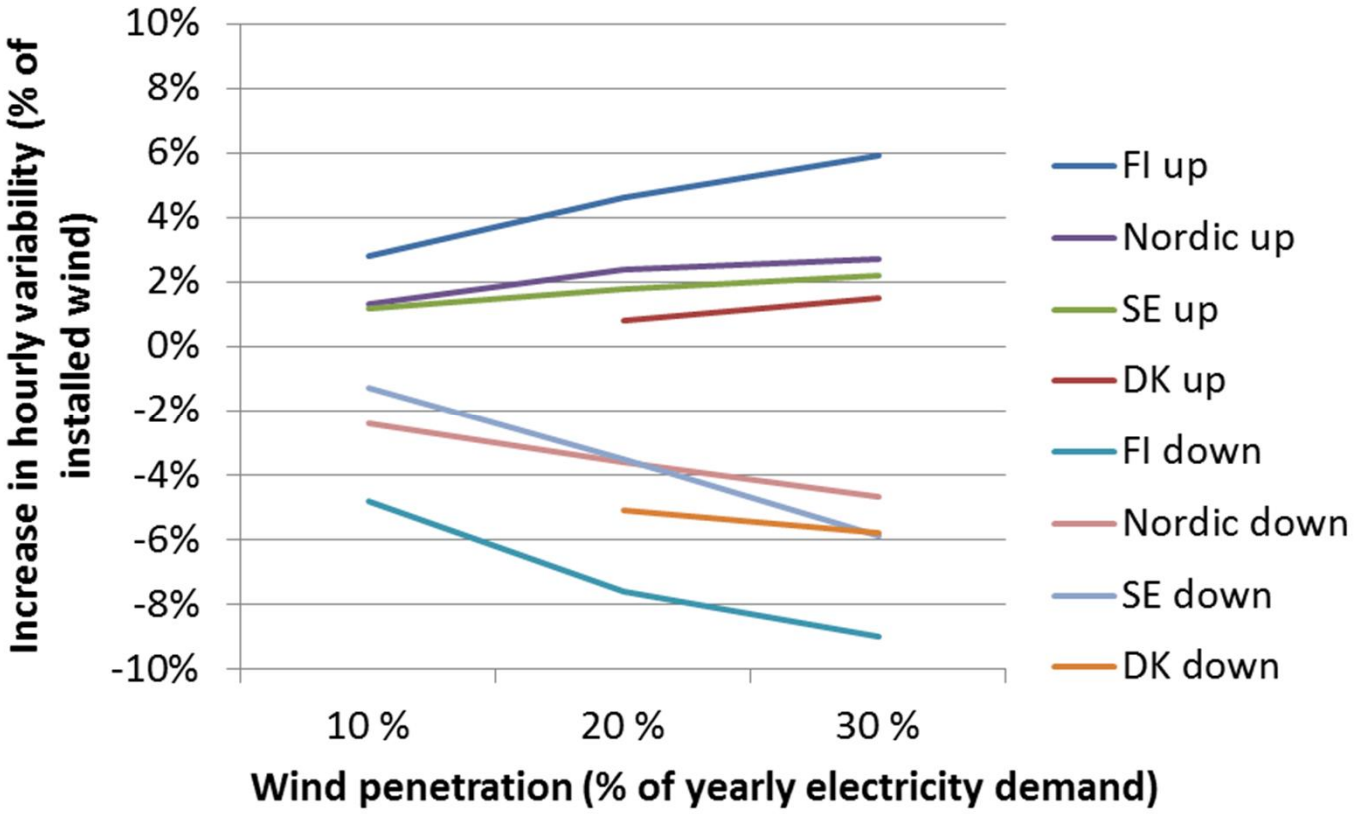
IMPACT OF WIND ON SYSTEM BALANCING IN NORDIC COUNTRIES

How much is wind increasing the variability that power system sees now through the load



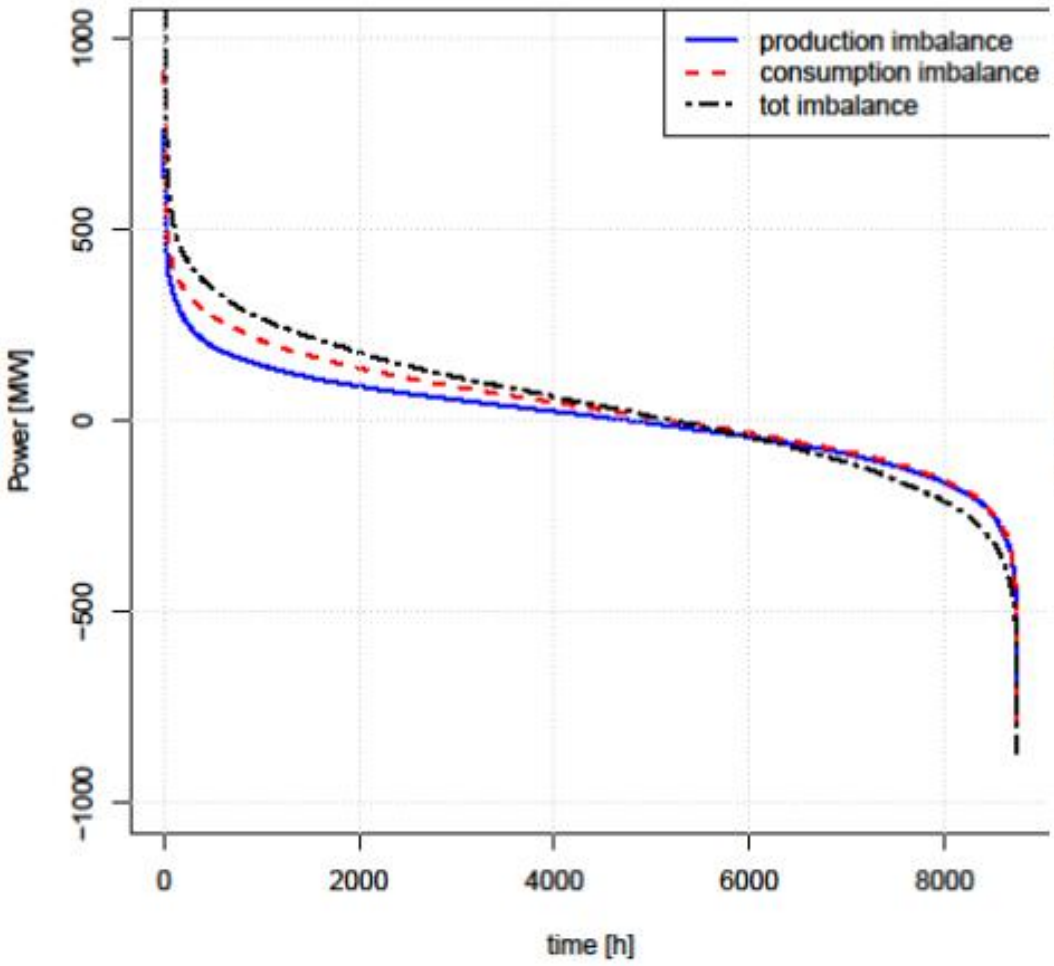
- Load and wind variability combined, with different amounts of (scaled) wind power production (FI and NO = 50 % of DK)

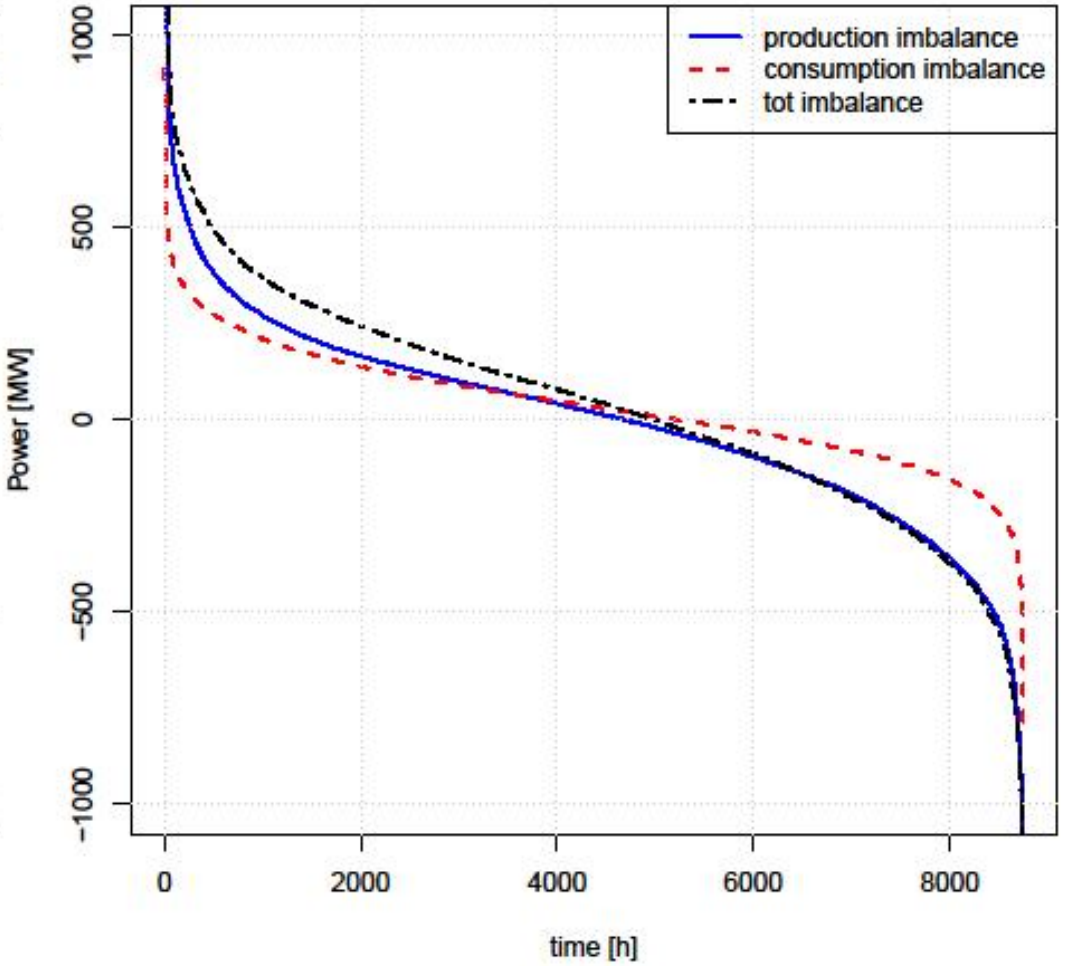
Hourly variability – impact in balancing need



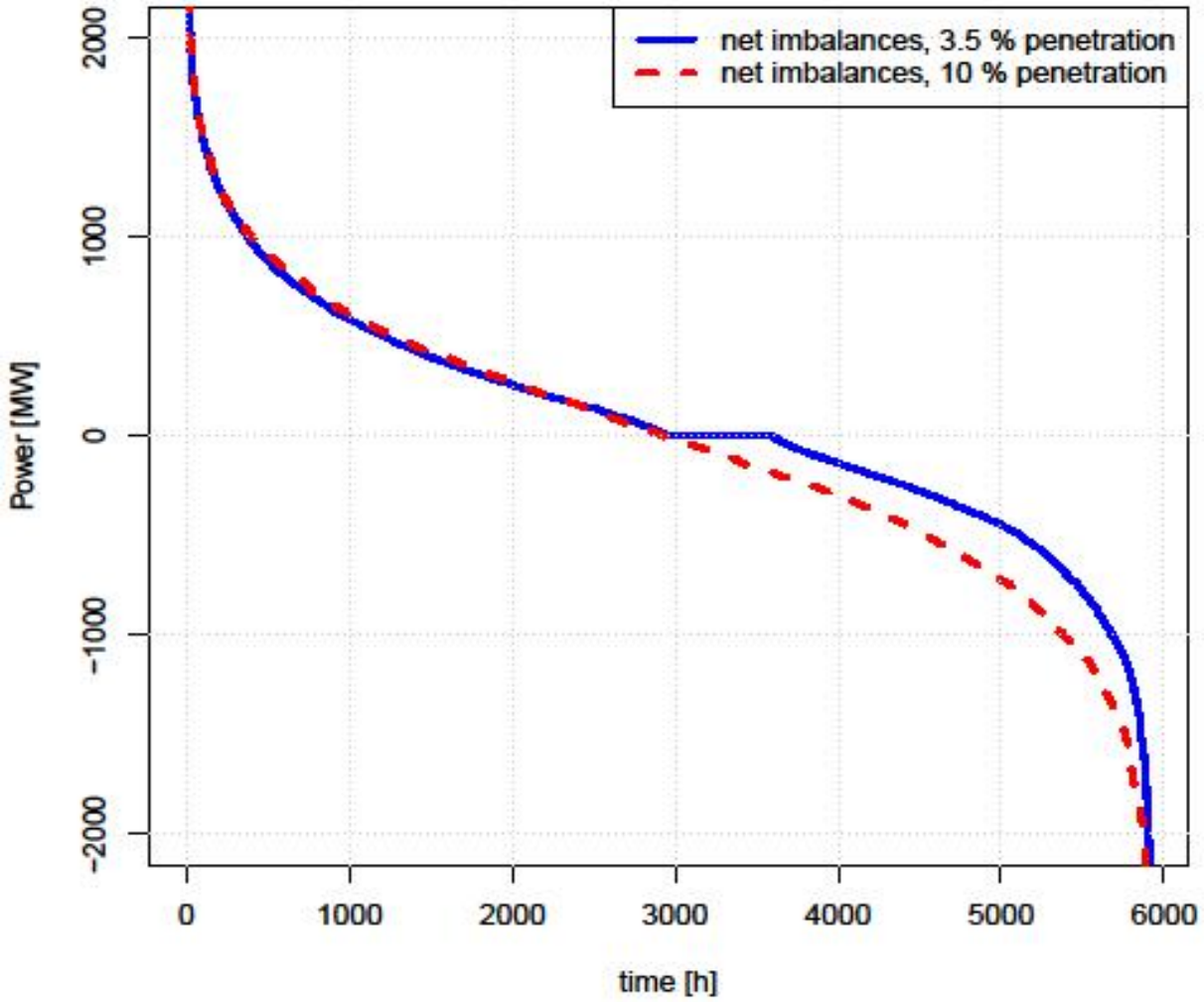
- 99.9 % exceedance level used as confidence level. Increase in hourly variability of net load, compared to load is presented as increase in balancing needs

Finland: imbalances with 4.5 % and 10 % wind share (from day-ahead forecast errors)



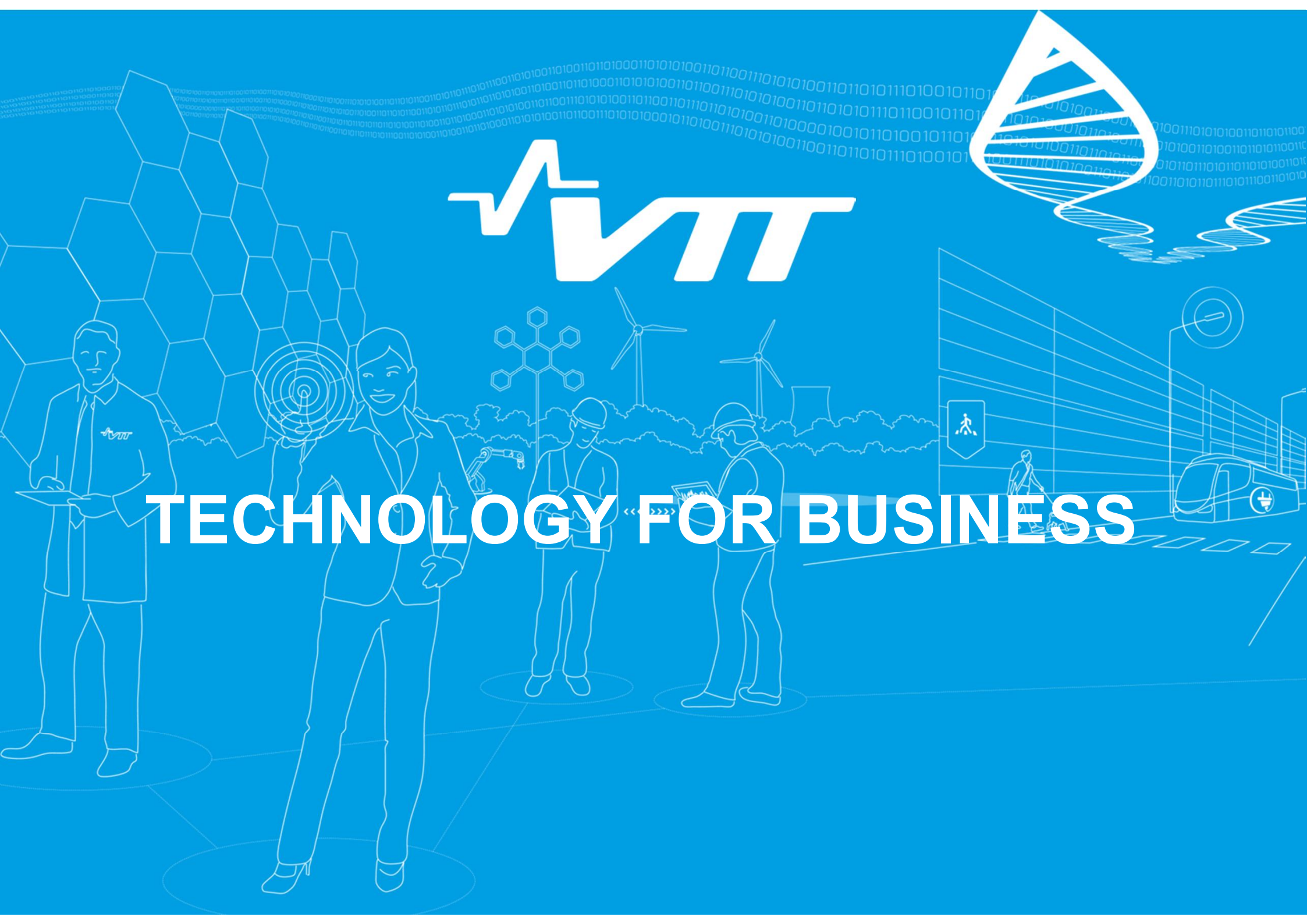


Nordic countries: Imbalances in with 3.5 % and 10 % wind share (from day-ahead forecast errors)



Planned work for Icewind end 2014-15

- Forecast errors: continue with analyses, two journal articles:
  - VTT/DTU/Kjeller: Smoothing impact, improvement of forecast accuracy
  - VTT: Impact on balancing: day-ahead and some hours ahead, in one country and Nordic wide, up-scaling existing wind, iImpact on balancing volumes (GWh) and prices/costs
- Storm analysis, one journal article (DTU, Kjeller, VTT)
- Impact of icing on forecasting accuracy (Kjeller, VTT)
- WILMAR model runs for power system impacts – one article (VTT)


TECHNOLOGY FOR BUSINESS