

Forecasting

Energinet.dk

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Facts about Energinet.dk

- TSO for electricity and gas in Denmark
- Independent public enterprise under the Danish Ministry of Climate , Energy and Building
- Owns and operates the electricity and gas transmission systems
- Co-owns electricity and gas spot exchanges
- Approx. 800 employees
- Annual revenue: approx. DKK 10 billion \approx US\$ 1.5 billion
- The consumers contribute to our activities through tariffs
- Our finances are based on a break-even principle – non-profit!
- Investment decisions are based on socio-economic welfare criteria

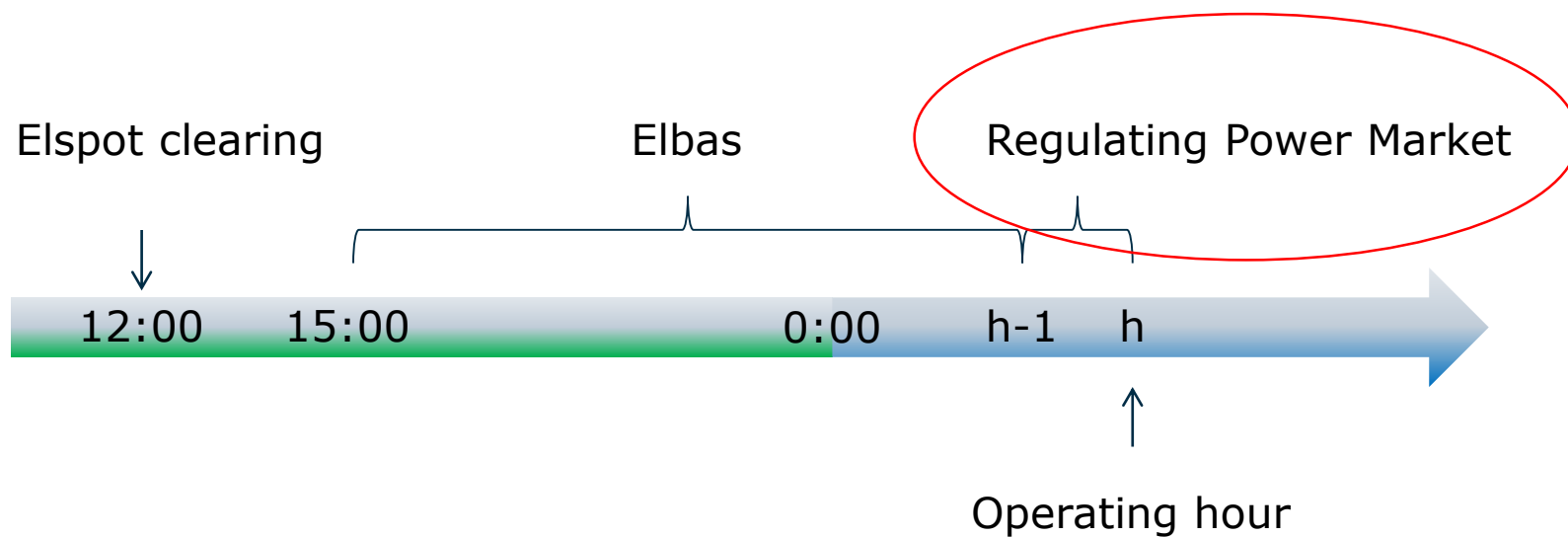


TSO: Transmission System Operator

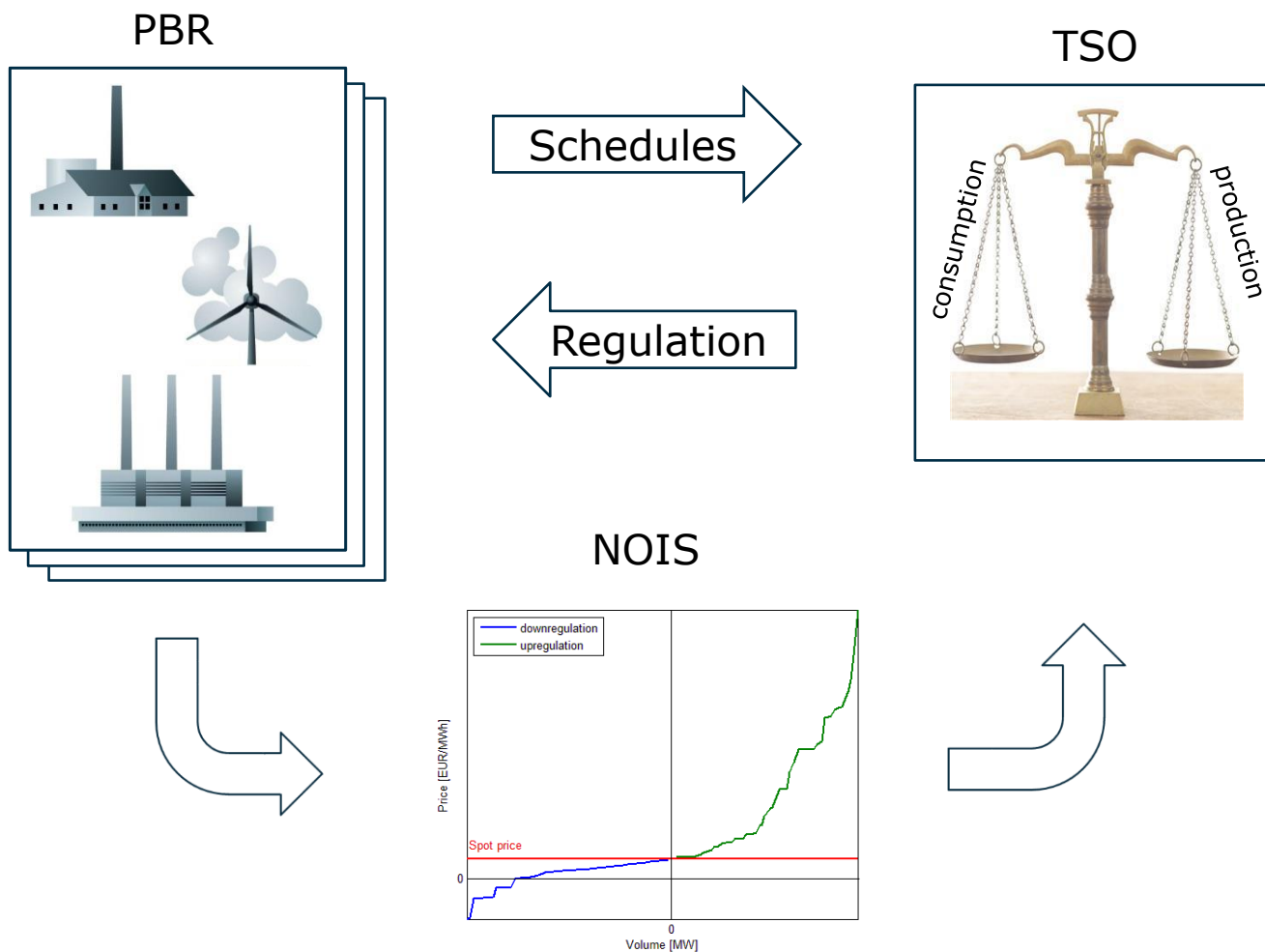
Why Forecasting?

- Balancing
- Reserve estimation
- Day ahead power balance estimation
- Trade transmission loss and production under a purchase obligation.
- Transparency
- ...

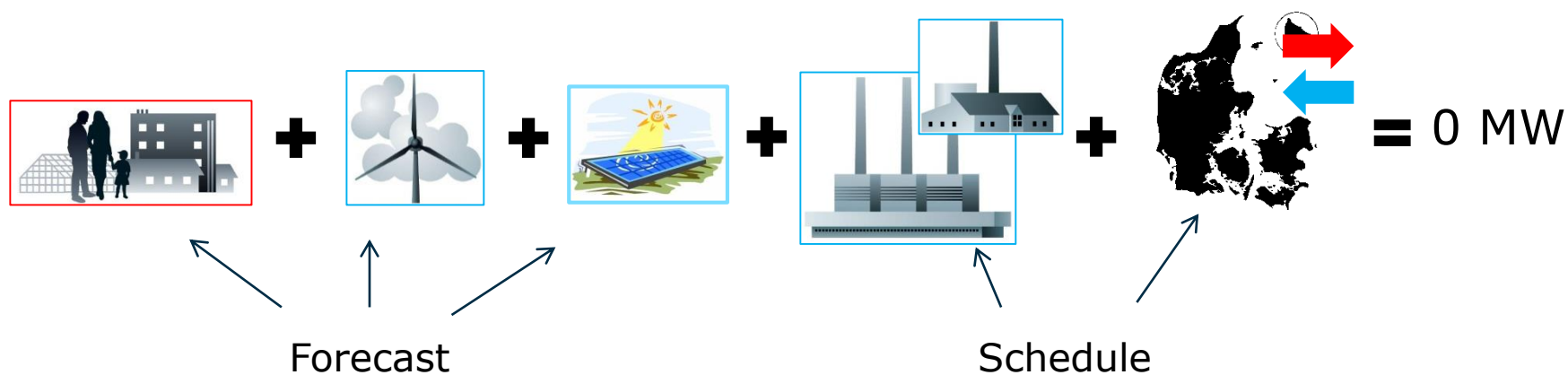
Nordic Electricity Markets



Regulating Power Market



Balance



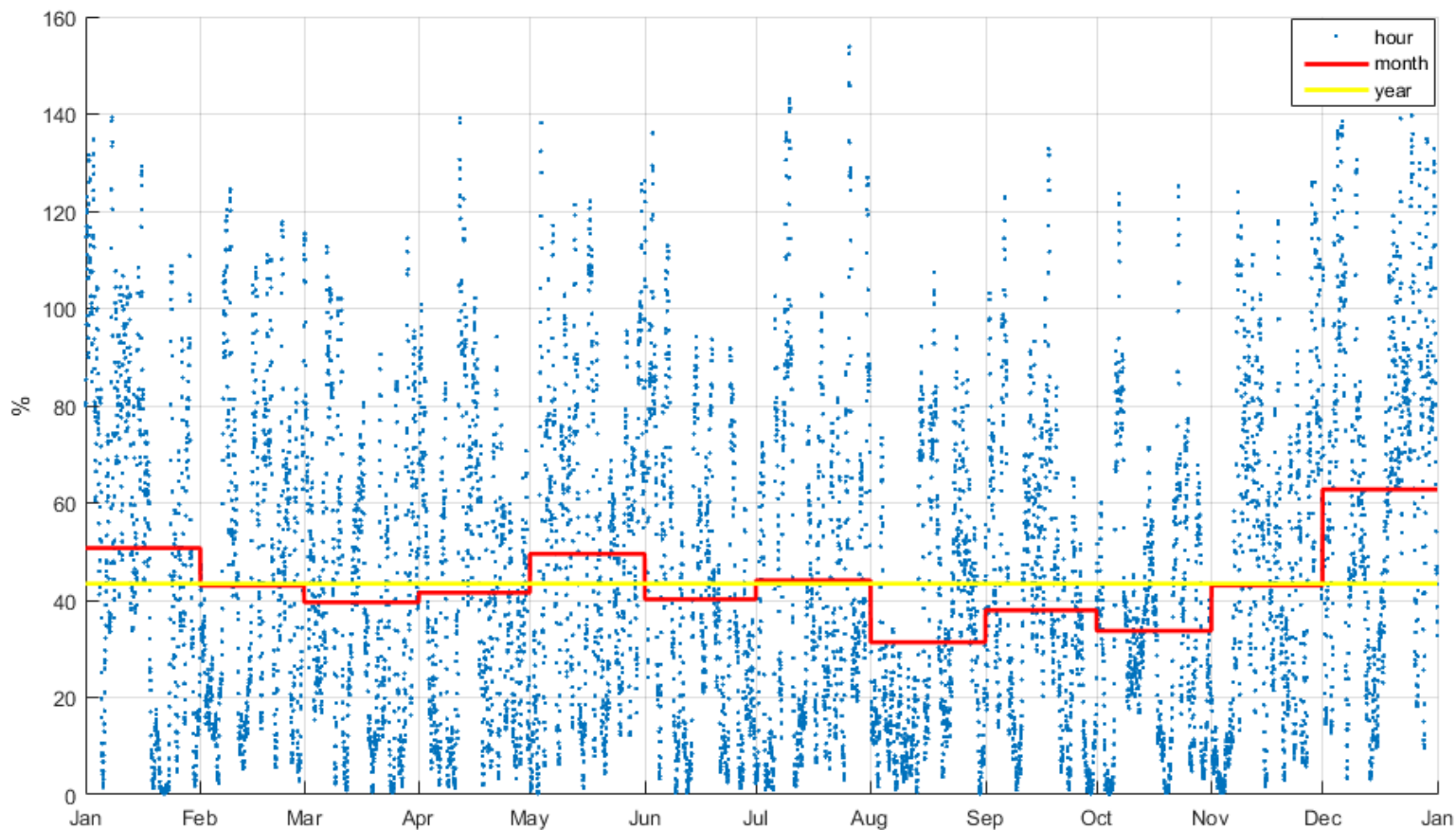
Positive

Negative

Wind Power



Wind Power Coverage, 2015



Wind Power Forecast

We use two forecasting tools – one external and one internal.

External forecast

- Provider: Enfor A/S
- Online forecast (0-12 hours) every 5 minutes
- Day ahead forecast (0-48 hours) every hour

Internal forecast

- Online forecast (0-10 hours) every 5 minutes
- Day ahead forecast (0-144 hours), triggered by new NWP

Each forecast is based on NWP's from three providers.

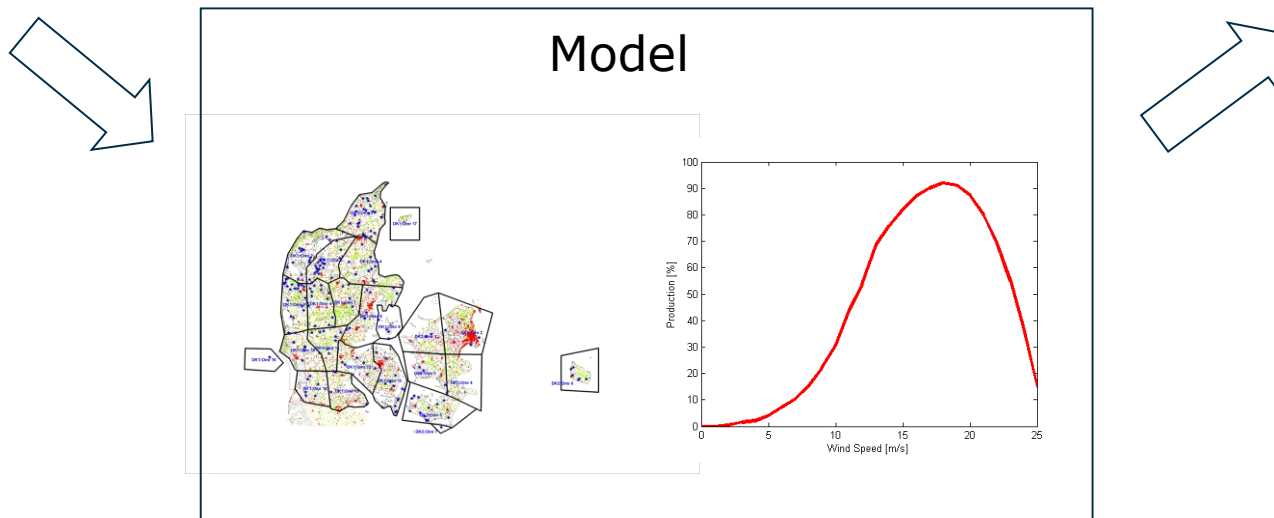
NWP: Numerical Weather Prediction



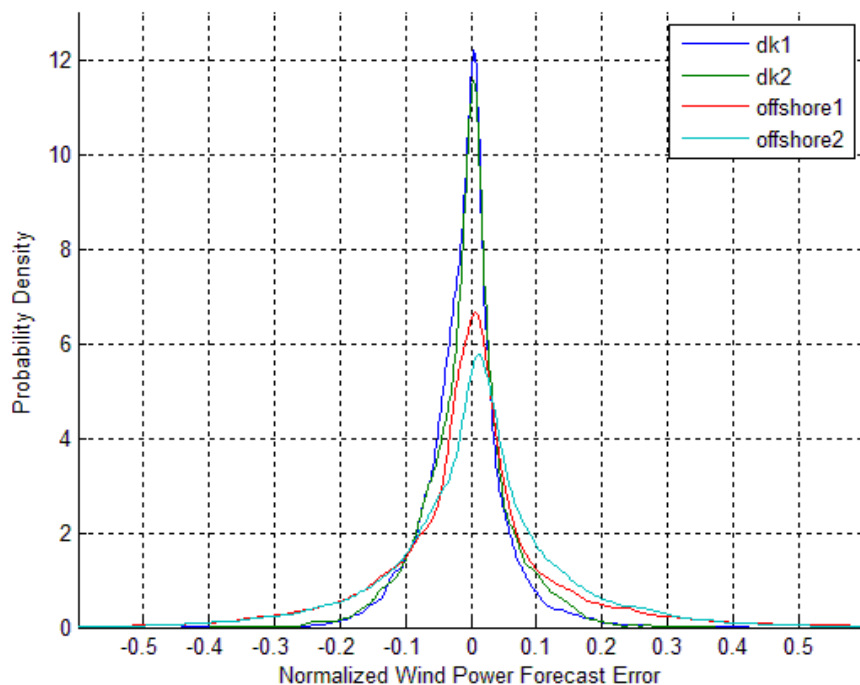
Internal forecast

- Wind speed
- Production data
- Installed capacity
- Georeference
- **Spot price**

Wind power forecast



Performance – day ahead



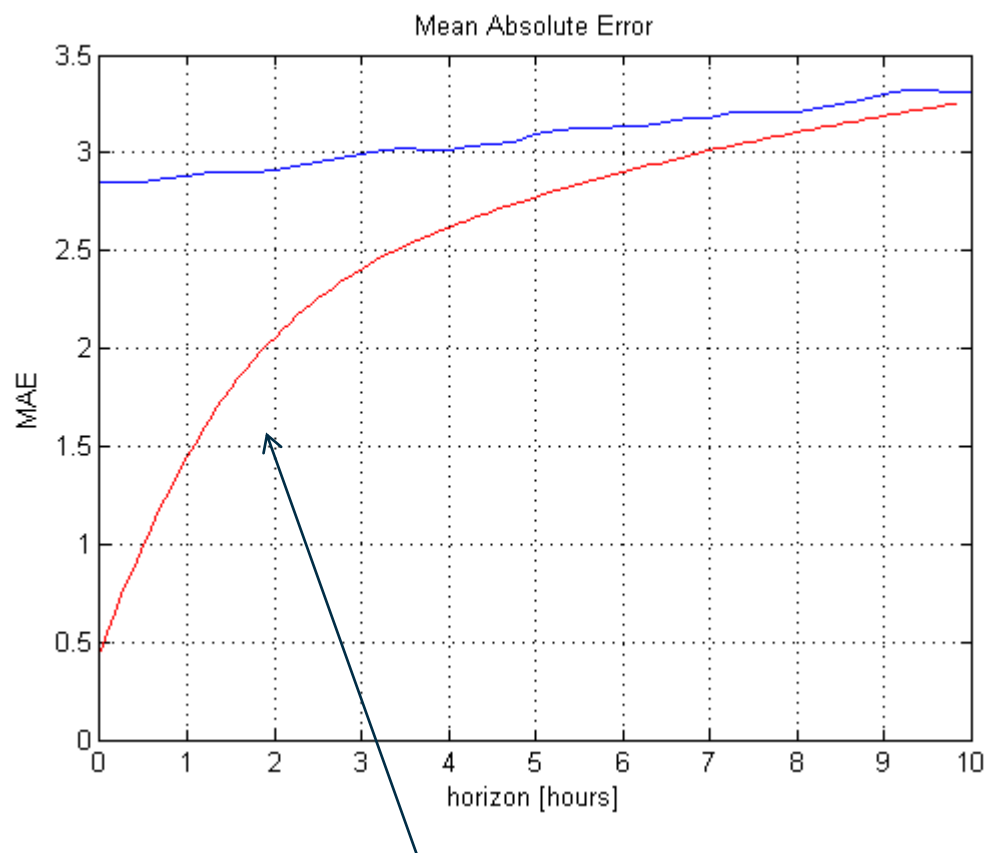
dk1 (3151 MW):

Mae	4,6 %
Rmse	6,5 %
Bias	-6,4 MWh

dk2 (679 MW):

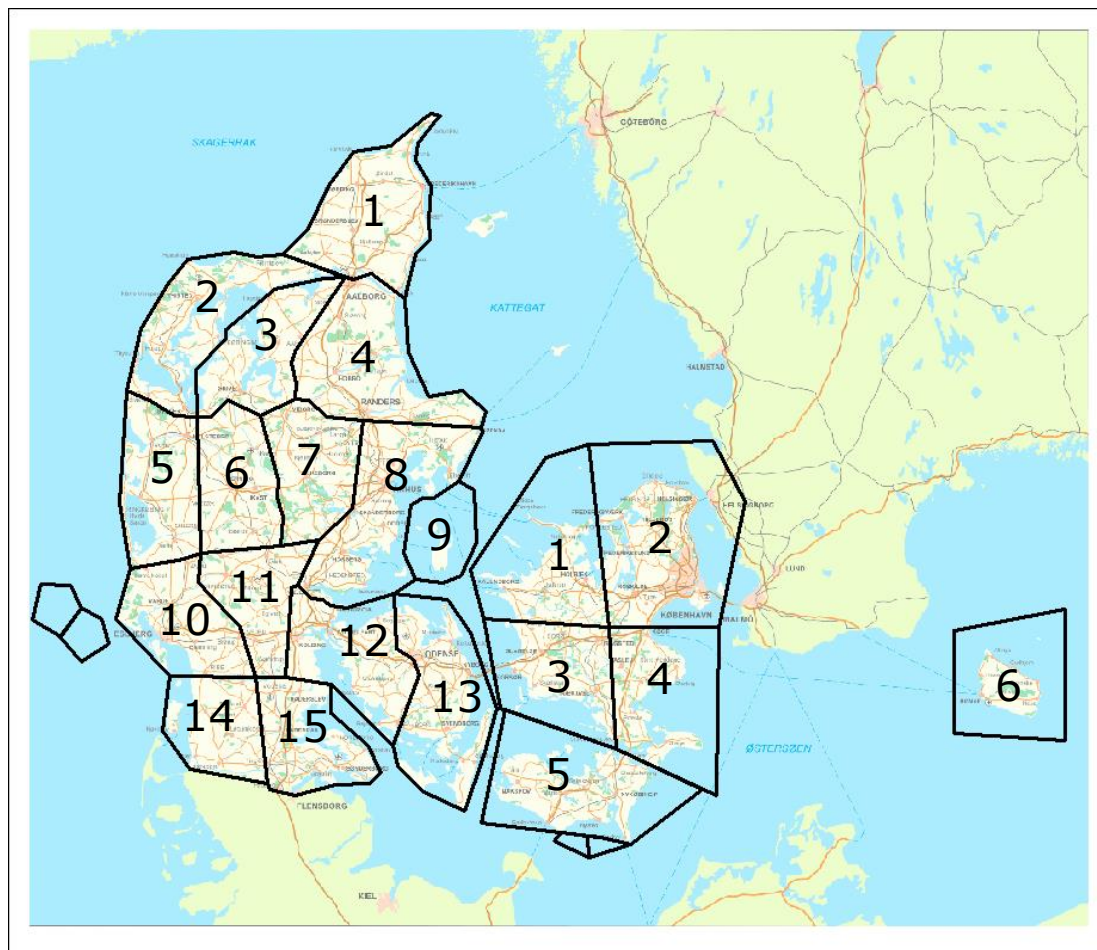
Mae	4,7 %
Rmse	7,1 %
Bias	-5,2 MWh

Forecast Performance



Spatio-temporal analysis

Spatio-Temporal Forecast Model



$S_a(t)$: scada value for area a at time t .

$P_a(h; t)$: offline forecast for area a time $t+h$ calculated at time t .

Spatio-Temporal Forecast Model

$E_a(h; t)$: offline forecast error for $P_a(h; t)$,

$$E_a(h; t) = S_a(t + h) - P_a(h; t)$$

In case of westerly wind, assume

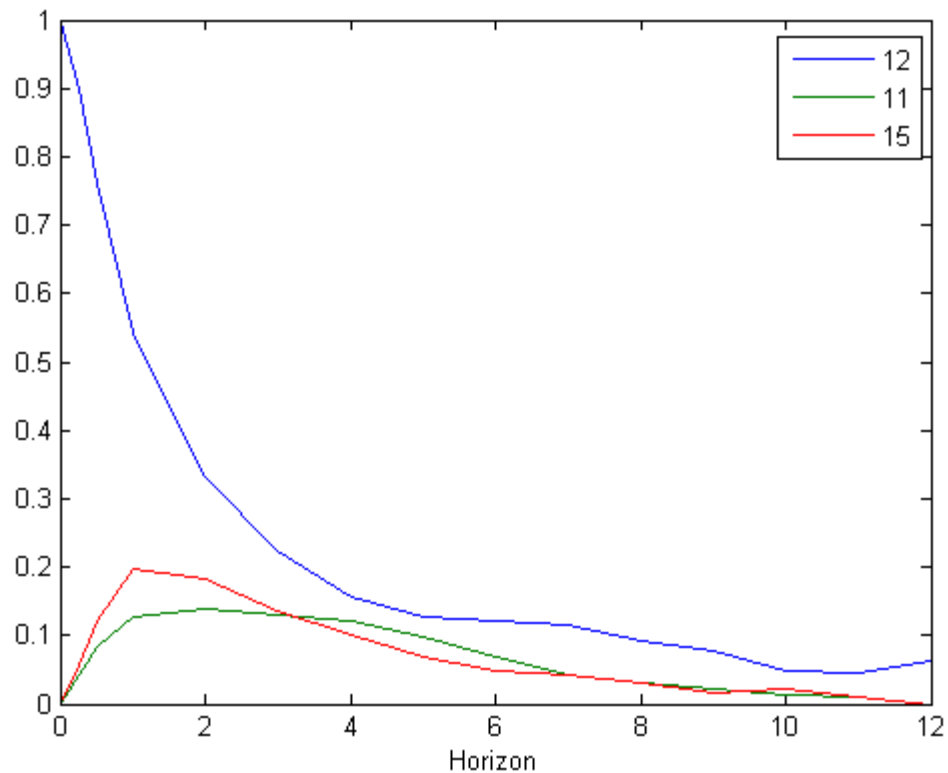
$$E_{12}(h; t) \approx a(h)E_{12}(0; t) + b(h)E_{11}(0; t) + c(h)E_{15}(0; t)$$

Likewise, for easterly wind,

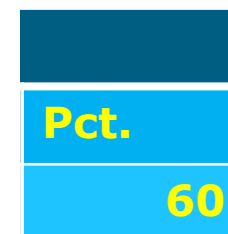
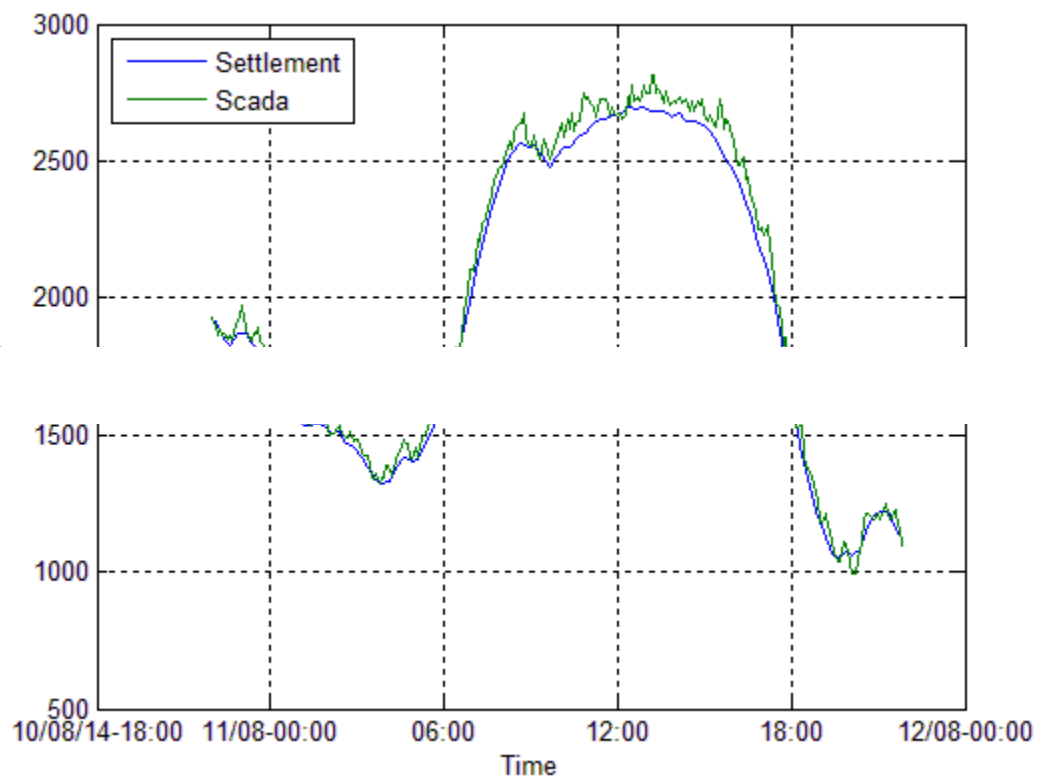
$$E_{12}(h; t) \approx d(h)E_{12}(0; t) + e(h)E_{13}(0; t)$$



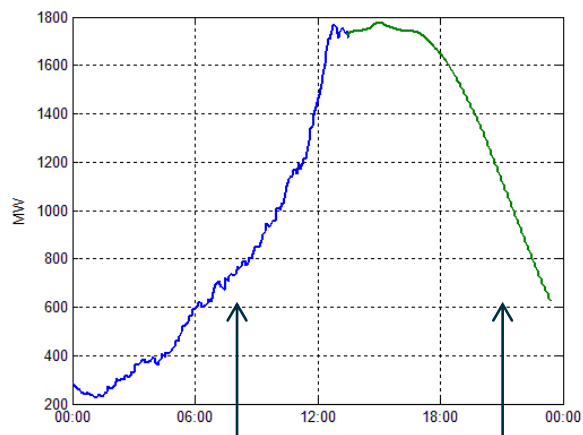
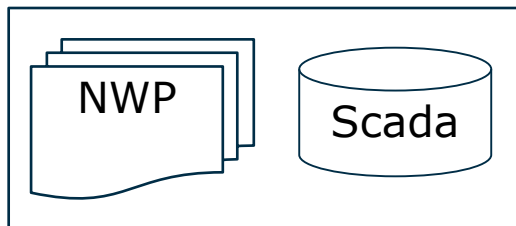
Spatio-Temporal Forecast Model



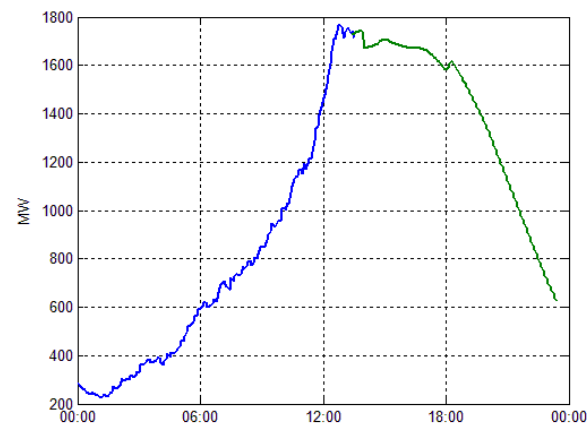
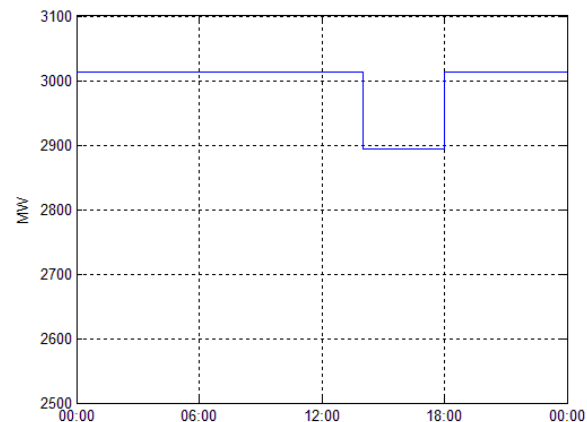
Online Measurements



Regulating Wind Power



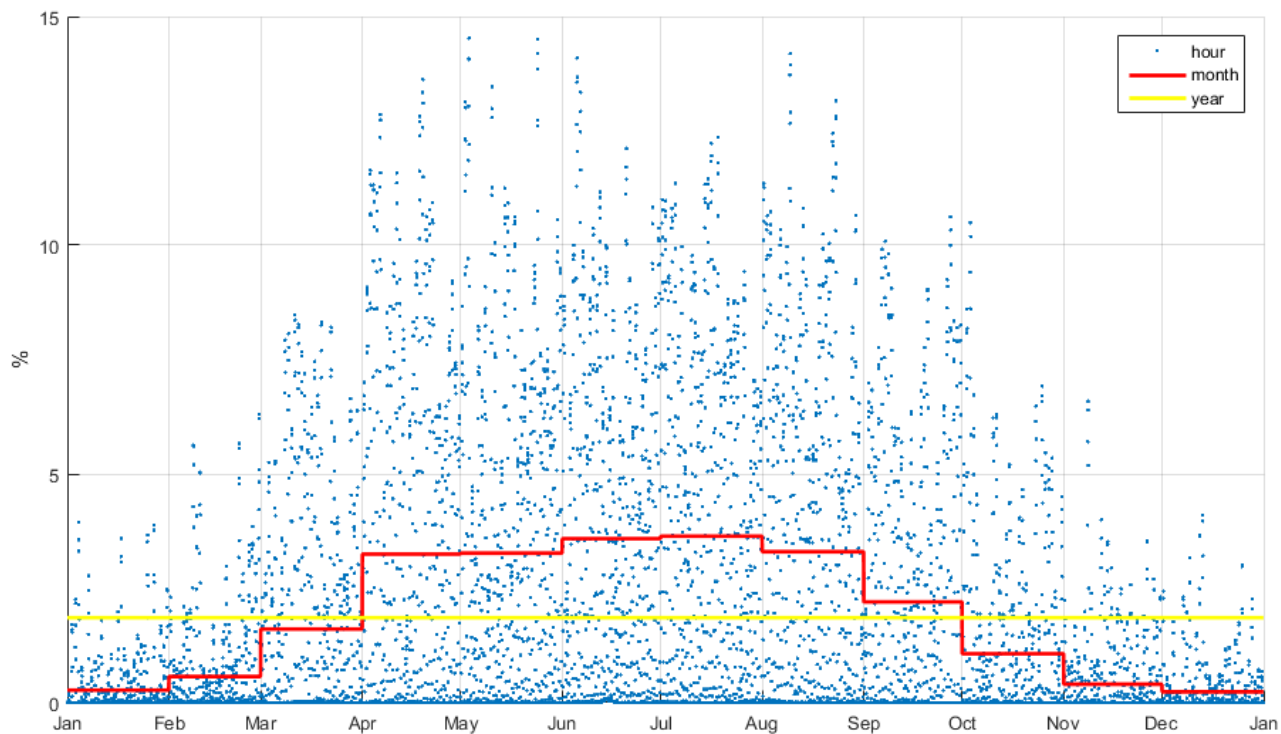
Scada Online forecast



PV power



PV Power Coverage, 2015



Clear sky Model

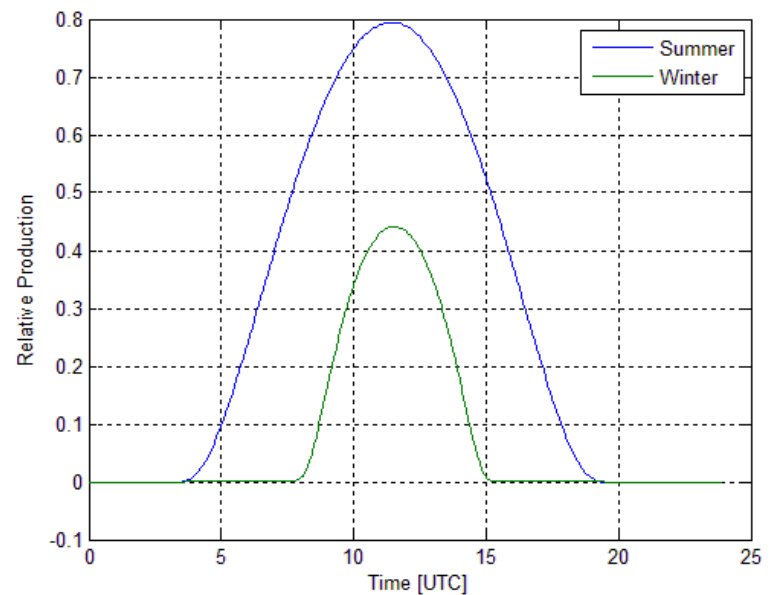
$$P \approx P_{inst} \cdot a^L \cdot \cos(T \cdot dt),$$

Where T is a constant,

dt : time to closest solar noon

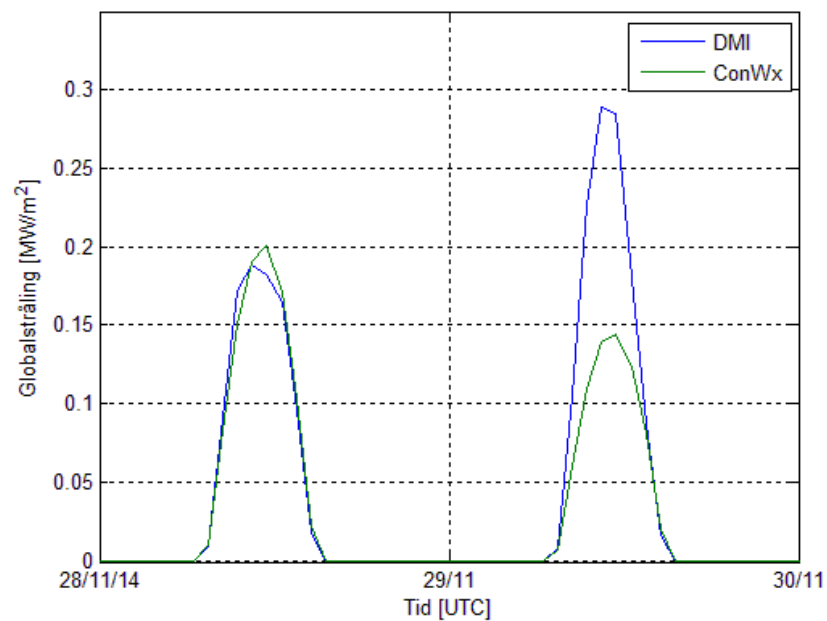
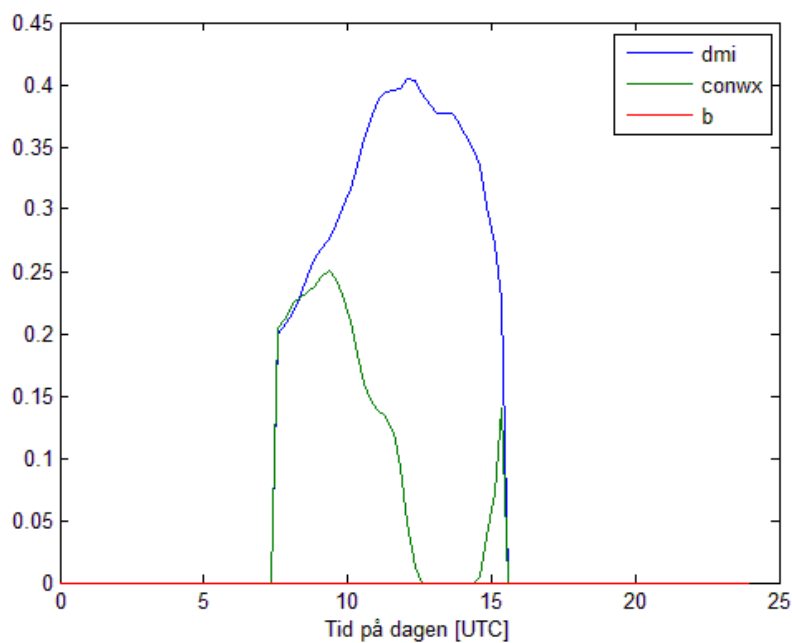
L : distance of radiation through the atmosphere

a : day-of-year parameter

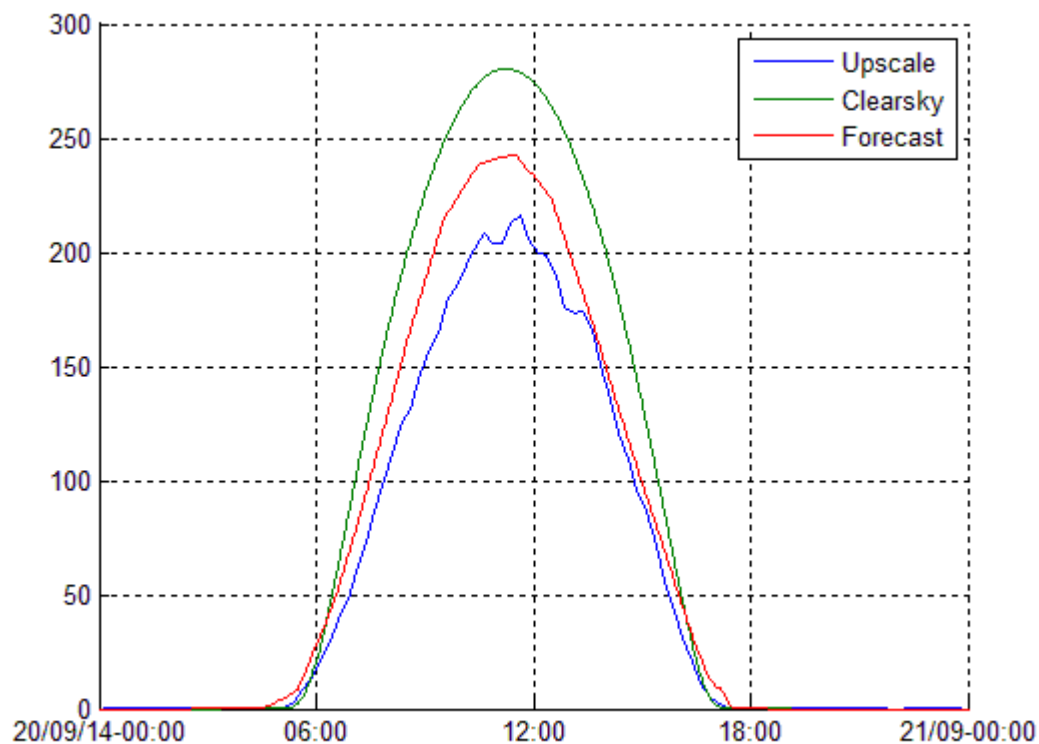


PV Forecasting

$$F(t) = w(t) \cdot nwp(t) + b(t),$$



Performance – day ahead



dk1 (518 MW):

Mae	9,1 MWh
Rmse	18,9 MWh
Bias	-1,5 MWh

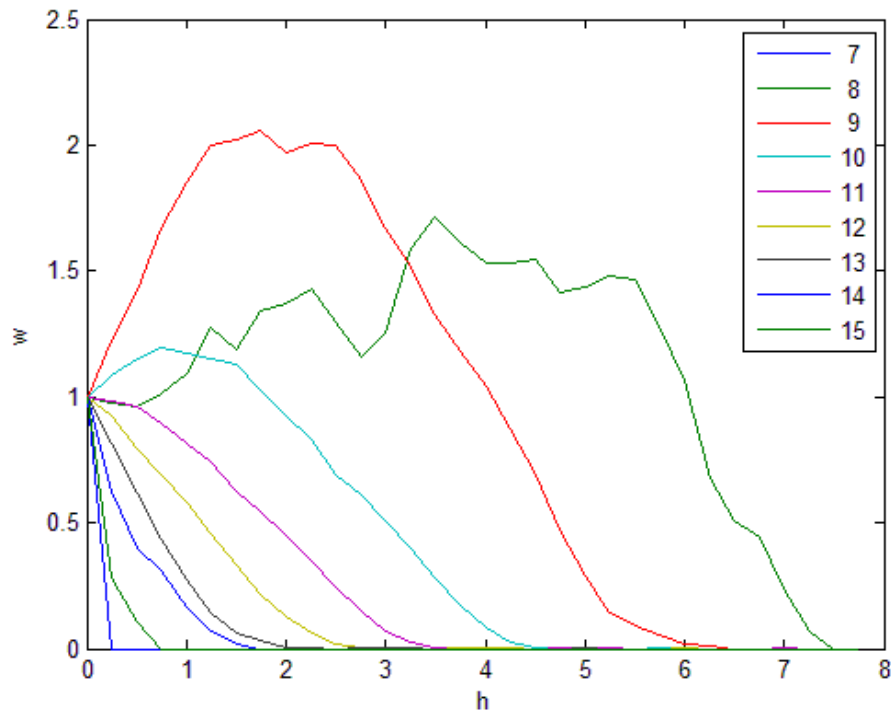
dk2 (266 MW):

Mae	4,7 MWh
Rmse	10,1 MWh
Bias	-0,4 MWh

Online PV Forecast

AR-model on offline forecast error

$$E(h; t) \approx w(t, h) * E(0; t)$$



Online Measurements

	Number of units			Inst. Cap. [MW]		
	Total	Online	Pct.	Total	Online	Pct.
Wind	3621	1350	37	3880	2324	60
CHP	880	319	36	1109	713	64