ENERGY, METEOROLOGY & THE PARADIGM CHANGE TO RENEWABLE ELECTRICITY

ICEM 2015

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Statkraft

STATKRAFT – A EUROPEAN LEADER IN RENEWABLE ENERGY

- Environment-friendly power generation: 56 TWh
- Gross operating revenues 2014: USD 6,724,980,000
- Total assets 2014: USD 21,597,700,000
- 3,700 employees in 19 countries
- Main power supplier to Norwegian industry
- 100% owned by the Norwegian state

European Flexible Generation

Market Operations

International Hydropower

Wind Power

District Heating

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Statkraft's production

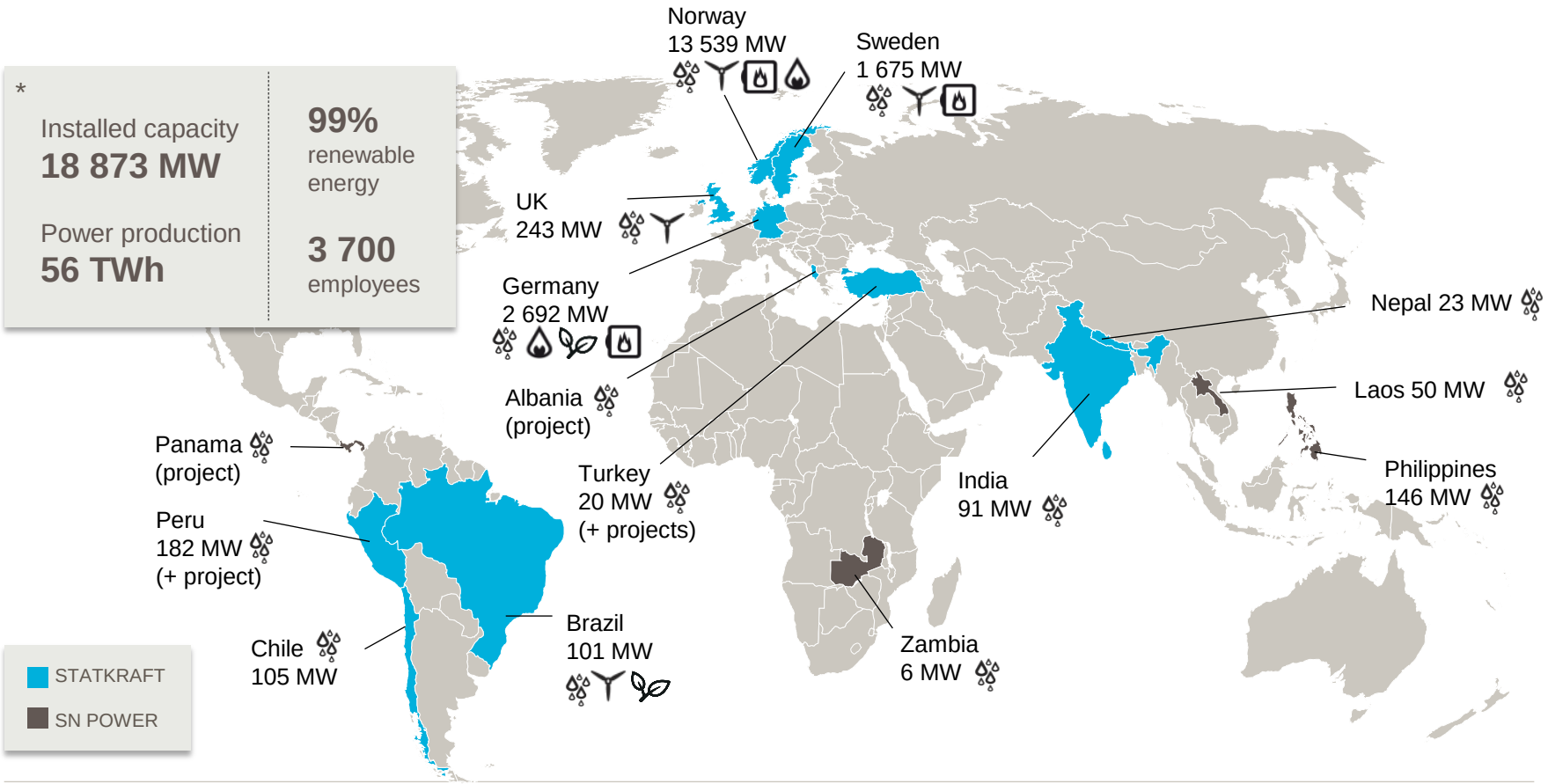
*

Installed capacity
18 873 MW

Power production
56 TWh

99%
renewable energy

3 700
employees



** 2014 figures. Includes: - Statkraft/SN Power's share of installed capacity*

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Corporate responsibility in Statkraft

Statkraft will deliver electricity based on **environment-friendly sources of energy**, use **sustainable**, **safe** and **efficient** production methods and behave in a **responsible** and **ethical** manner in the market.

A century of experience

- Statkraft's history is tightly linked with the development of hydropower generation in Norway

- Power plants and business operations date back as far as the end of the 19th century

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Maintain and develop flexible hydropower

Tysso 1

- European leader within hydropower
- More than 340 hydropower plants in Europe, whereof 2/3 in Norway
- Generating capacity of more than 13 600 MW
- 1/4 of Europe's reservoir capacity
- Close to 40 small scale hydropower plants in operation, generating more than 400 GWh/year.

Onshore wind power in Norway, Sweden and UK

- Developing onshore wind power through SAE Vind and Fosen Vind in Norway, and in cooperation with SCA and Södra in Sweden
- Norway
  - Hitra, Kjøllefjord and Smøla (installed capacity: 244 MW)
- Sweden
  - Em, Stamåsen, Tollarpabjär and Mörttjärn-berget (installed capacity 171 MW)
- UK
  - Alltwalis, Baillie and Berry Burn (installed capacity 143 MW)

Lead operator in offshore wind power in UK

- Owner* and operator of Sheringham Shoal offshore wind farm (317 MW)
- Offshore wind farm Dudgeon* is under construction (402 MW)
- Offshore wind farm Triton Knoll** under development (up to 900 MW)
- Several 1200 MW-projects on Doggerbank*** under development

** In partnership with Statoil, ** In partnership with RWE Innogy, *** With partners through Forewind Ltd*

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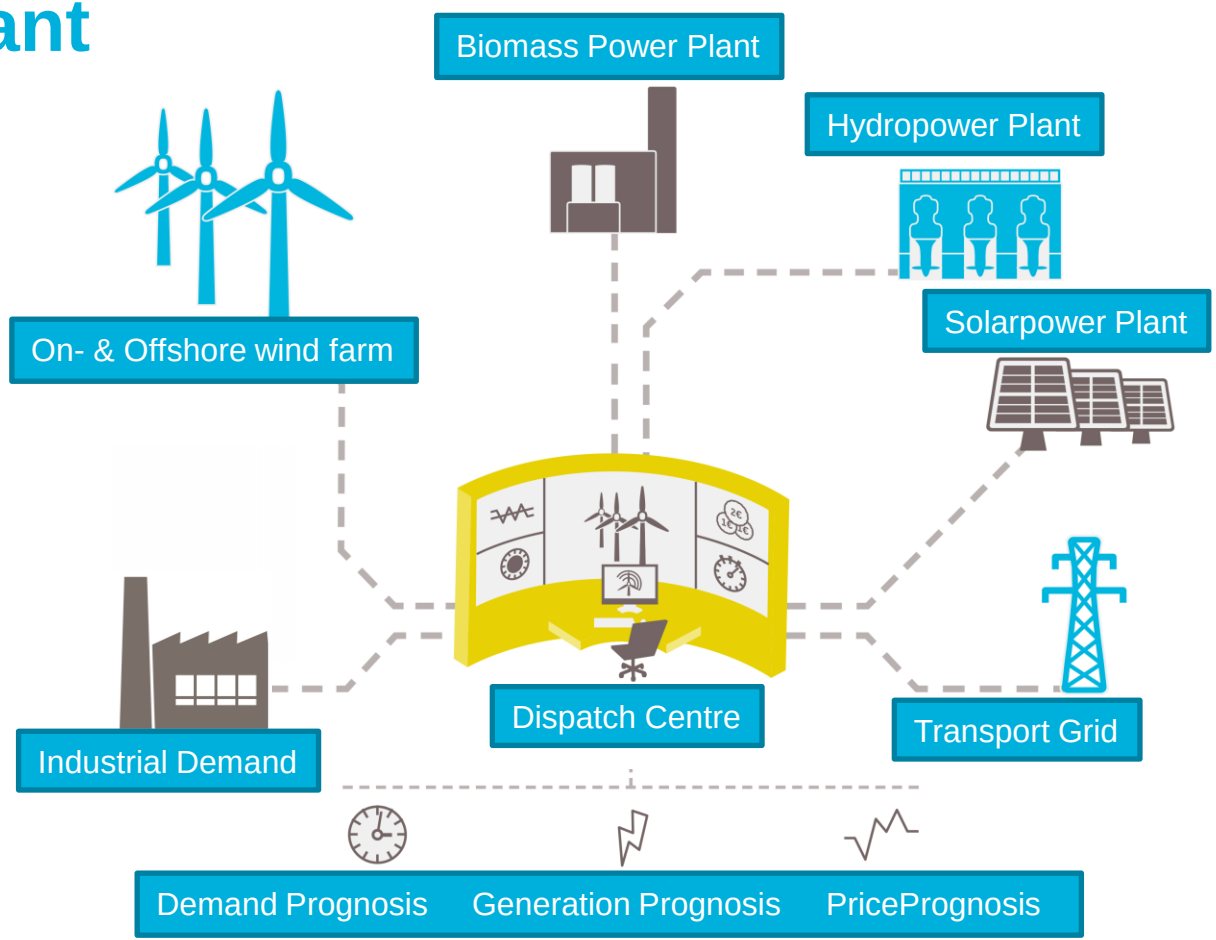
Virtual Power Plant

- First VPP in Germany
- Largest VPP in Germany
- Total generation 8000 MW
- Communicating with every individual plant
- Able to balance supply and demand



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A global player in energy market operations

- Statkraft is one of the main traders within the European power market
- Special expertise within physical and financial power trading
- Statkraft is active in all energy-related commodities, offering origination and energy service agreements
- Expanding power trading activities in Europe, as well as in Brazil and India.

WEATHER & POWER TRADING

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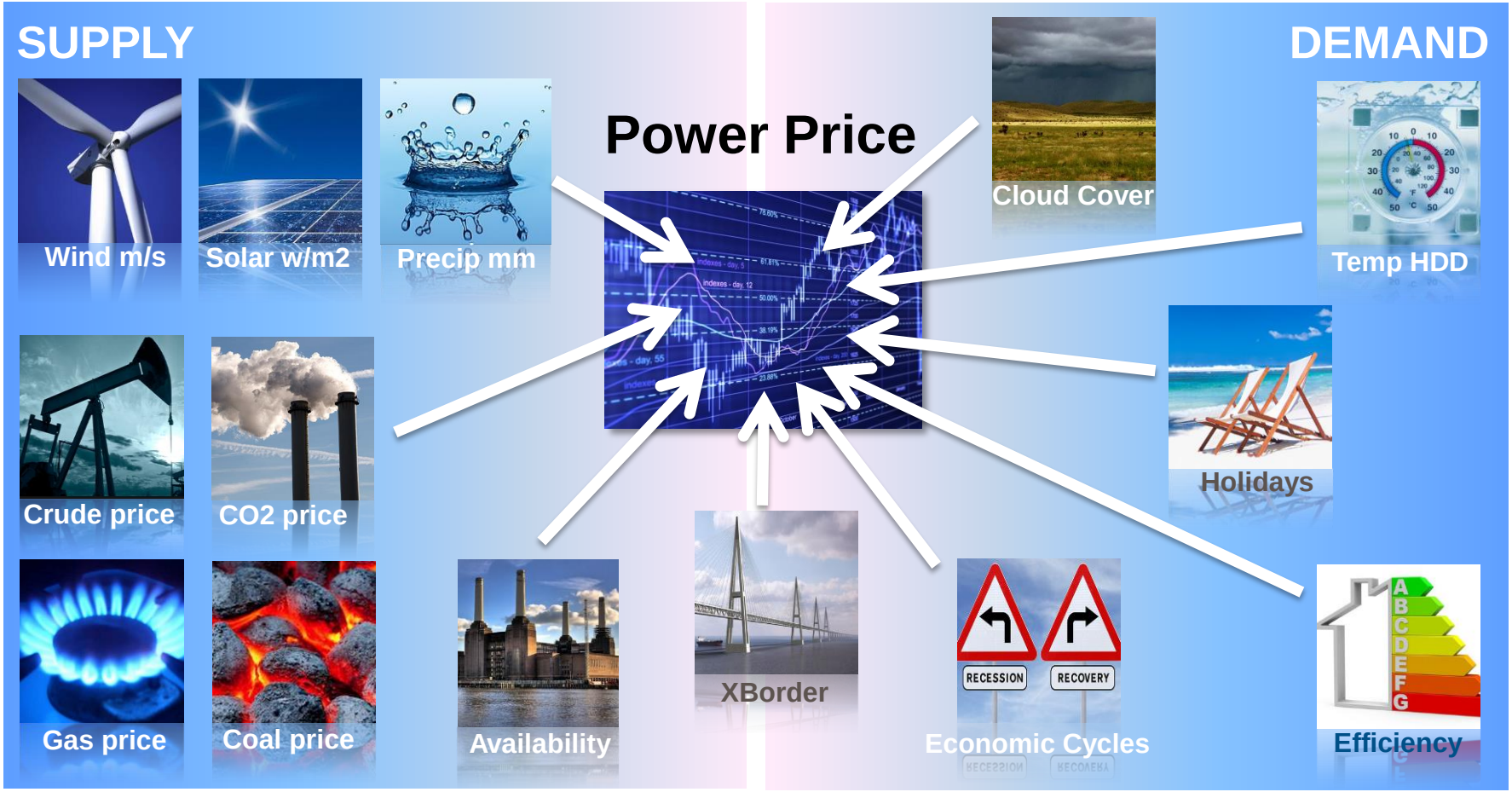
How Weather Elements Work On Commodity Prices



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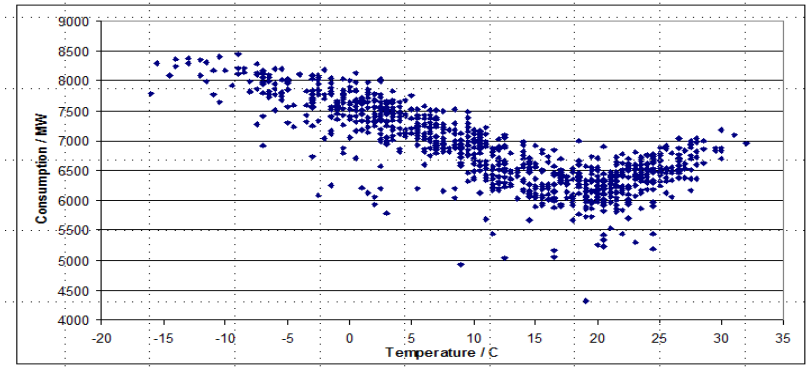
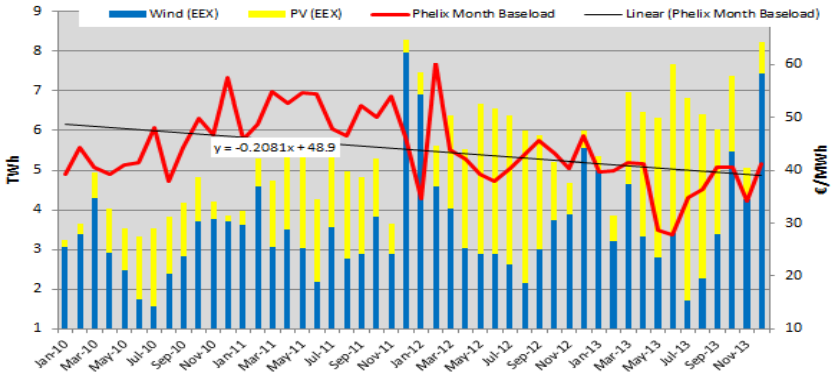
Different Markets – Different Weather Elements

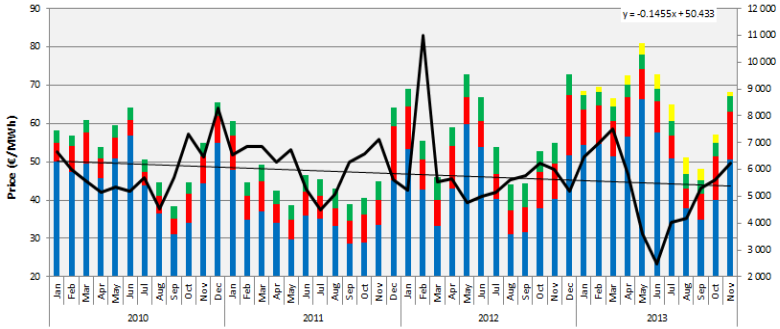
Temp vs Load Romania



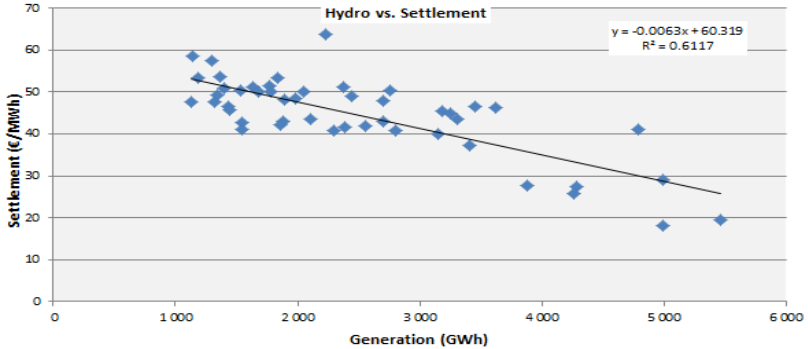
Phelix base month vs RESgen in Germany



Phelix base month vs RESgen in France



Hydrogeneration vs Settlement in Spain



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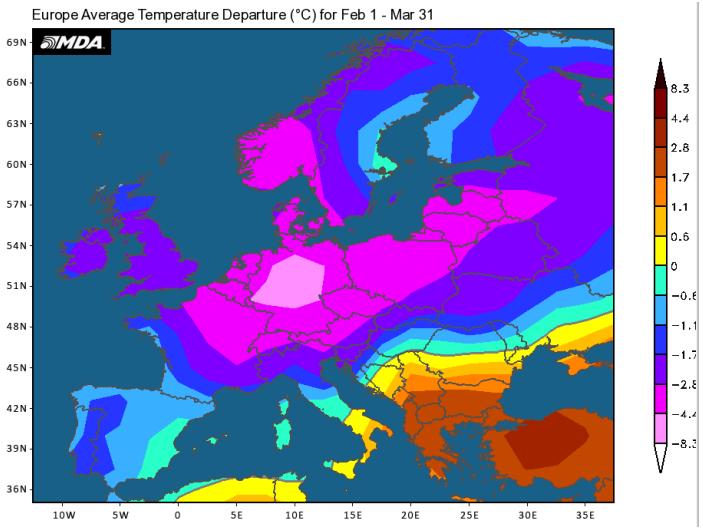
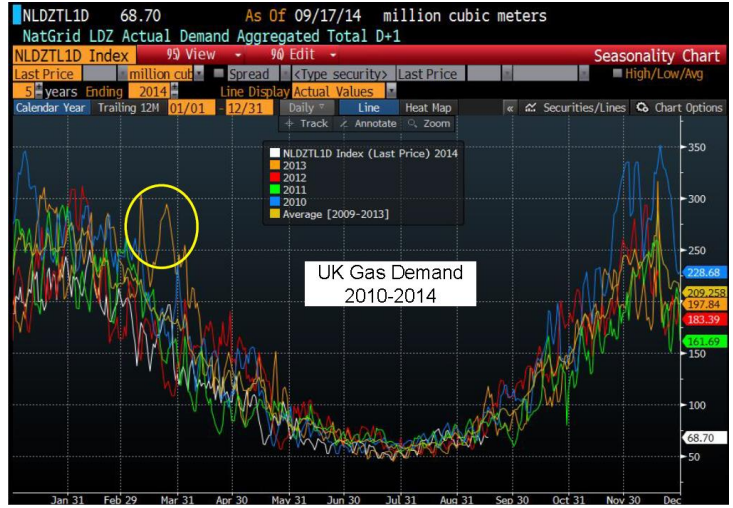
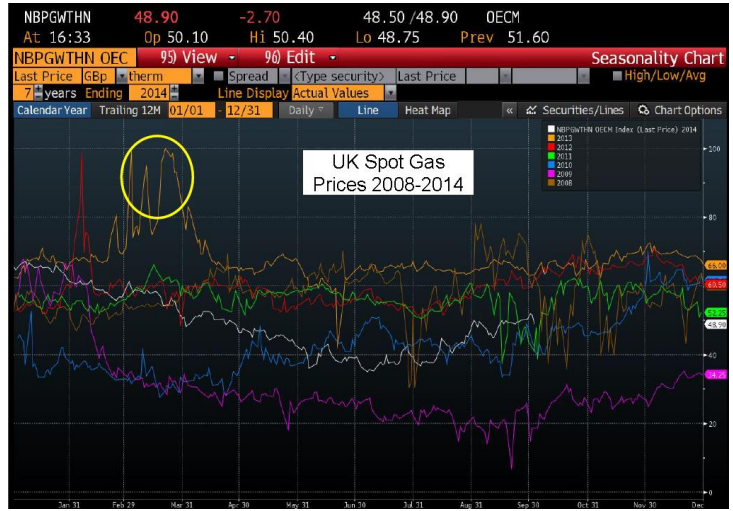
Cold Winter of 2013







- Cold Snap in Feb/Mar 2013 led to high Heating Demand
- Leading to very high NBP Gas Prices

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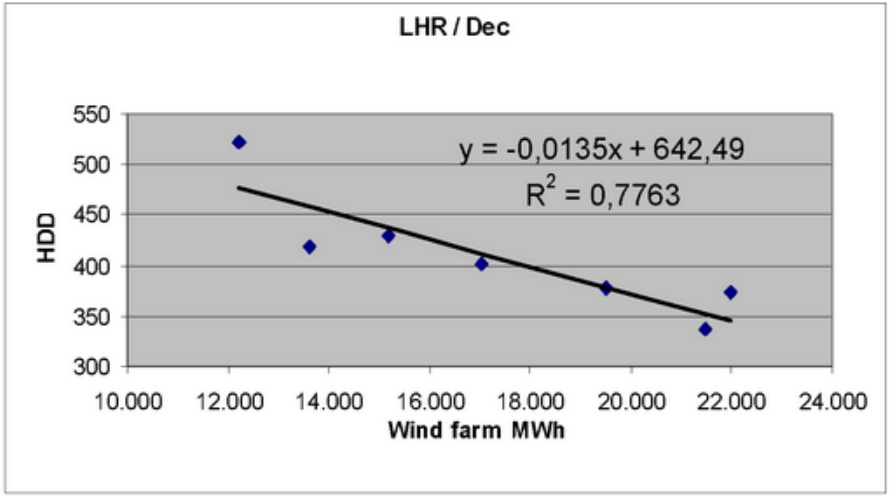
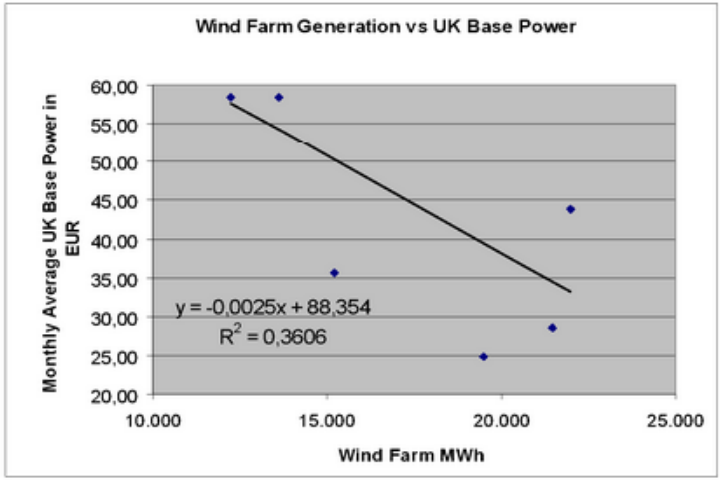
Even worse: cold winters are calm winters





- Correlation between a wind farm generation figures in the UK and London-Heathrow winter temperatures

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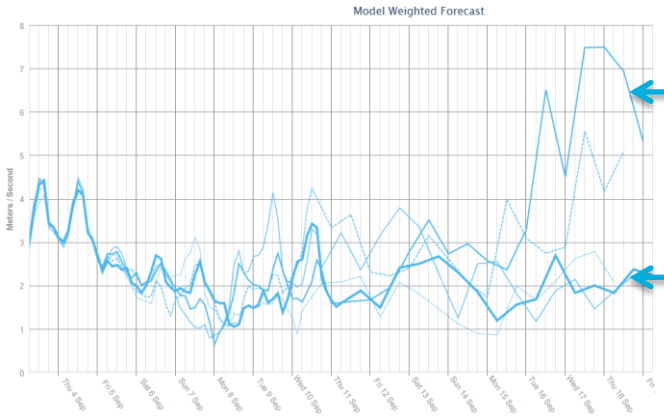
The Evolution of Weather as a Fundamental Factor for Power/Gas Markets

- Weather was a volume risk on the **demand** side
- With the onset of renewable electricity generation it became a volume risk on the **supply** side, too
- Producers, retailers and traders needed meteorological expertise
- The **weather forecast** itself eventually turned into a **price risk**



GFS00op wind forecast caused market reaction

GFS06op wind forecast did NOT caused market reaction

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The Cascading Forecast Concept

- Risk = Probability x Impact

There are also trading opportunities out of past weather conditions (drought, long cold period)
Probability forecasts require ensemble predictions systems (EPS)

The Three Key Questions for a Trading Meteorologist:

The market sees it cold / warm - but what is our view?

How do we come to a forecast decision?

How we express our confidence and how / when does it change?

Ensemble Prediction Systems (EPS) – Coping with Uncertainty

- People / clients often don't want to deal with probability forecasts. They want straight answers: "jacket or no jacket". They want strong statements. A probability forecast is seen as weak, creating too many false alarms and loop-holes.
- The most important task for a Meteorologist is teaching his audience to understand and use EPS instead of deterministic forecasts.
- Prerequisite: Mets / Forecasters must be able to use them themselves
- Most people interpret a 66% chance simply as "yes" (33% chance as "no"). The Energy Trading Sector is a good example for a community that understands and uses probability forecasts (e.g. wind forecast) and knows that even an 80% chance is still not a sure bet.

Some facts about Ensemble Prediction Systems

- Upper air charts usually more skillful than surface charts as surface parameters are affected by sub-grid scale uncertainty not resolved by the model
- An EPS is only as good as the model it uses. If a model is unable to represent certain phenomena the EPS will also be unable to resolve it (small scale systems / convective storms).
- Always use the entire spread. Extreme members are not unrealistic only because one (the forecaster) thinks so.
- Use as many additional information as possible. Persistence, climatology, surface parameters etc., but preserve the freedom to decide against the model, if you have a good reason.

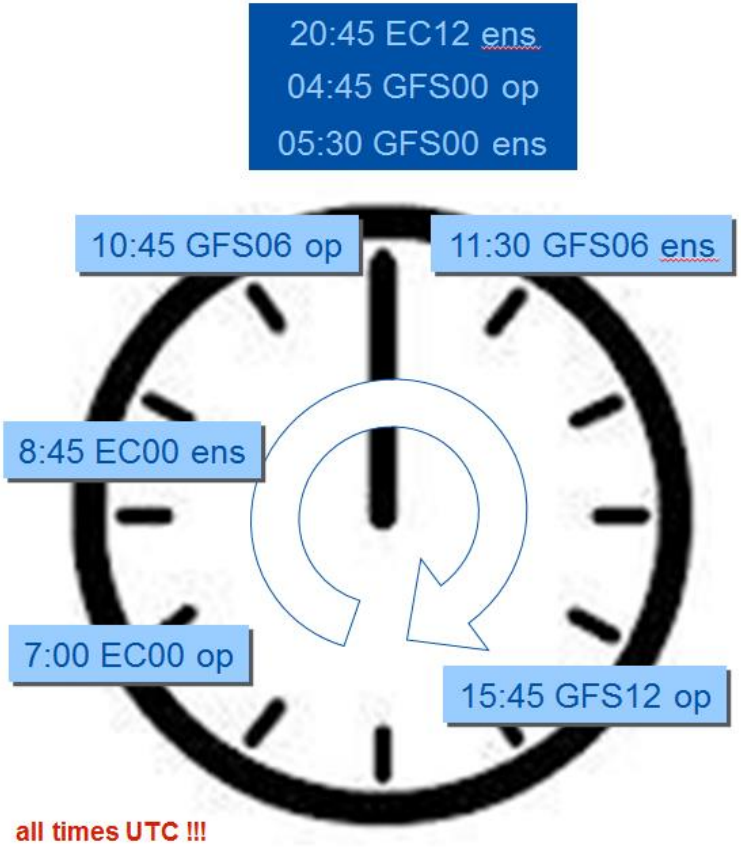
Numerical Weather Prediction – Clockwork NWP

Gas & electricity prompt markets react on subtle changes during the operational updates

The forecasting benefit of 1deg K change in e.g. the 10-15 day period is small, but there are times when markets react on even those (e.g. Feb 2013).

France & Nordpool seem to follow the EC00 op, most European markets the GFS 06op, the UK and the US also the GFS12 op

Constantly “new information” into the market from both models AND realization



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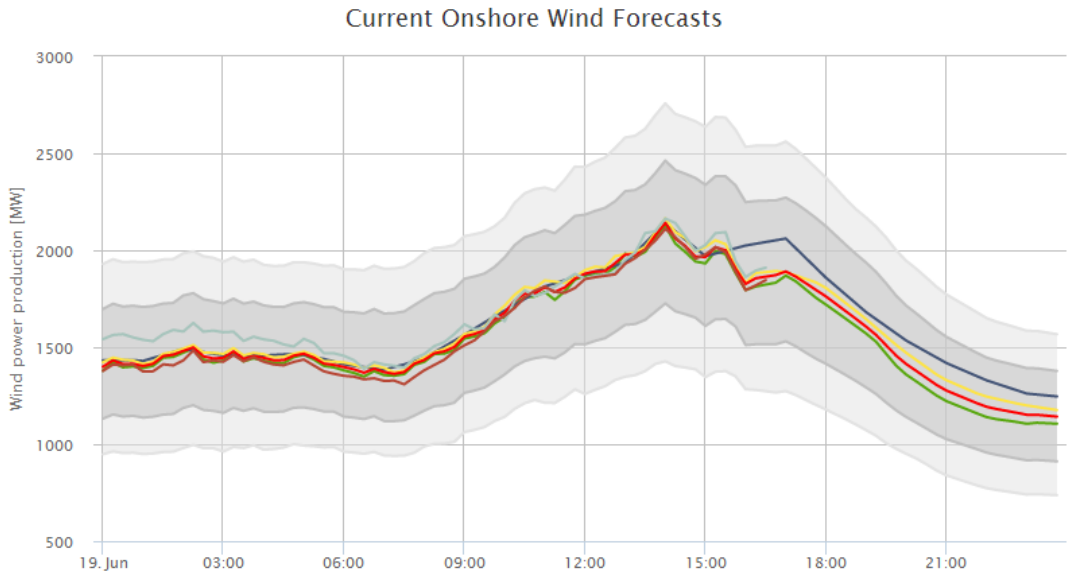
Intraday and Day Ahead Forecasts

Buzz Words:

- High frequency up-dating
- Nowcast
- Planetary Boundary Layer
- Nested Models
- Neuronal Networks
- Turbine Types / Characteristics



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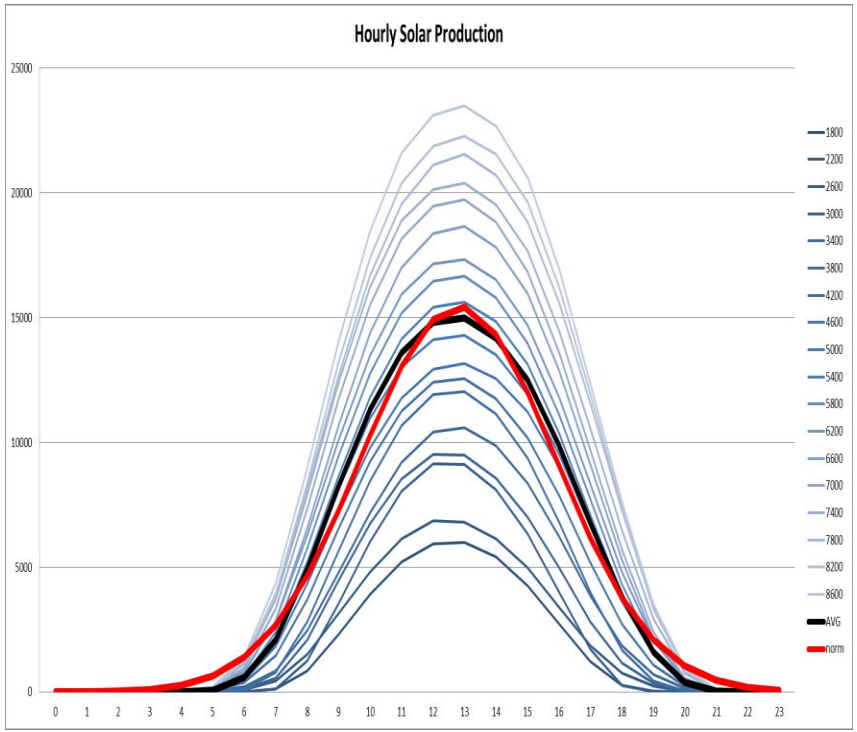
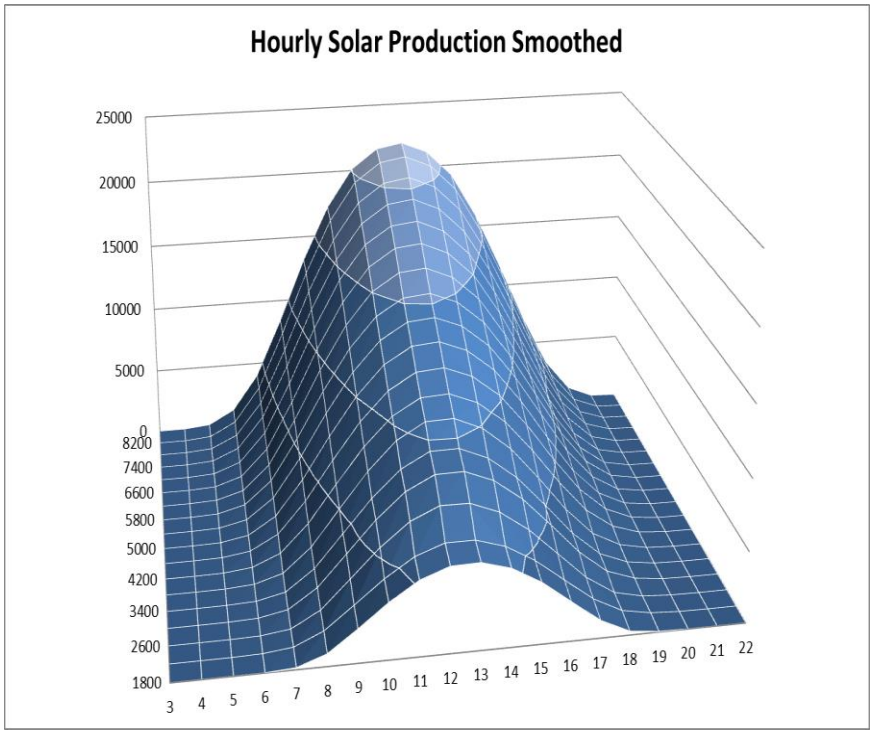
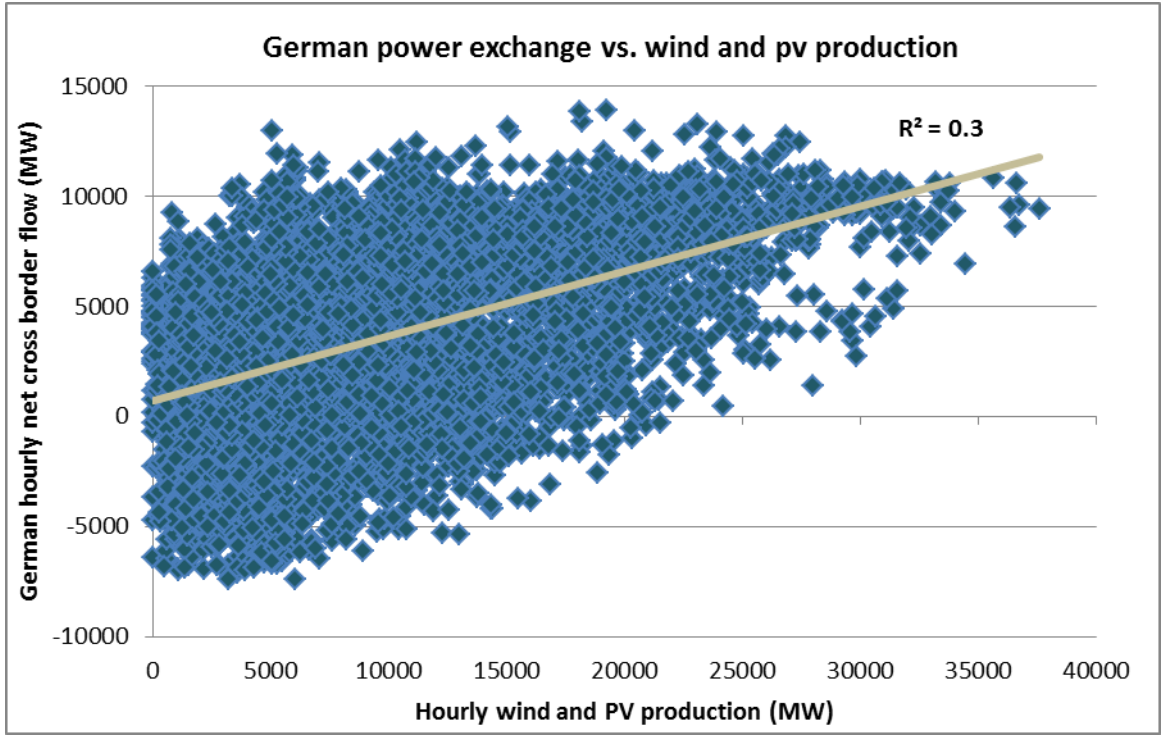
Hourly Solar Production for Summer Months





German power exchange driven by RES



* Data from year 2014, positive values = power exports

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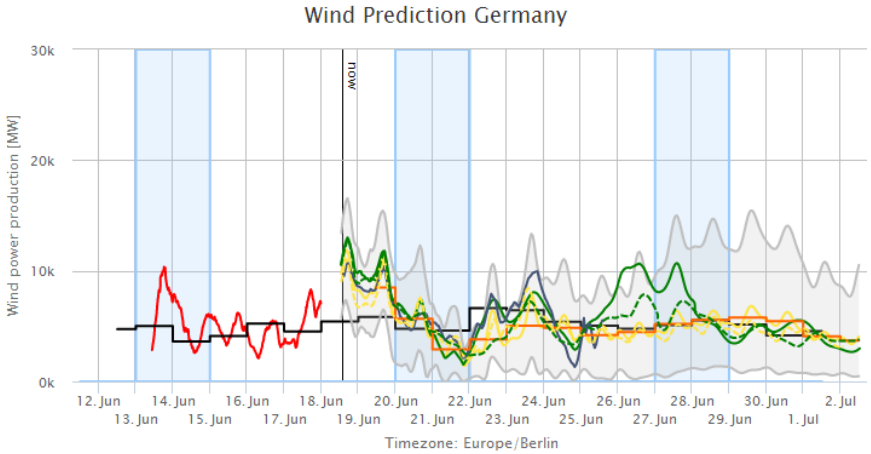
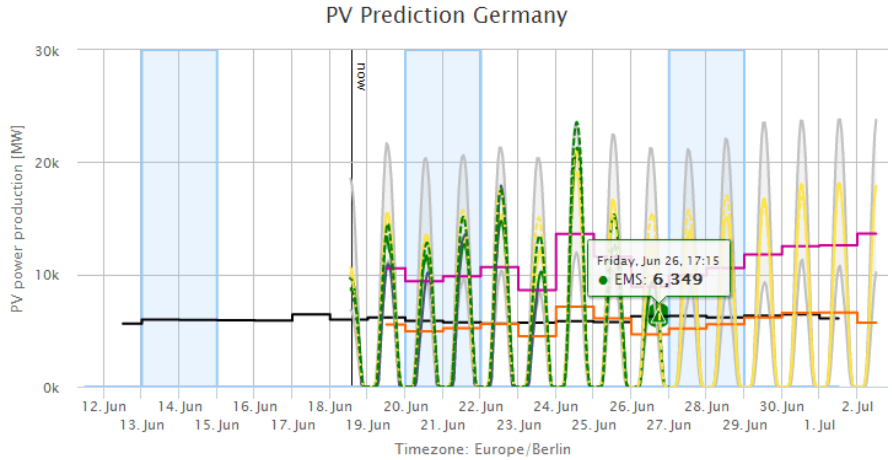
Front Week and Week Ahead Forecasts





Buzz Words:

- Main NWP Models (GFS, EC)#
- Up-dating every 6 hours
- Deterministic Predicition
- Ensemble Prediction
- Directional, not exact
- Meteorologist Interpretation
- Proprietary trading
- Risk Scenarios
- IN HOUSE VIEW

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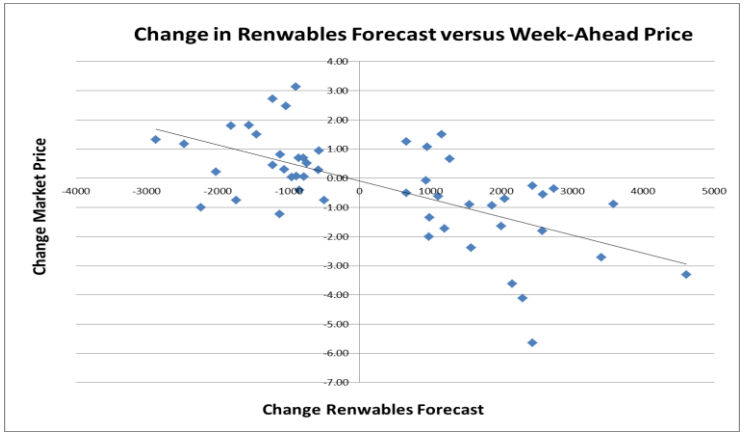
Correlation between Power and Renewable Forecast

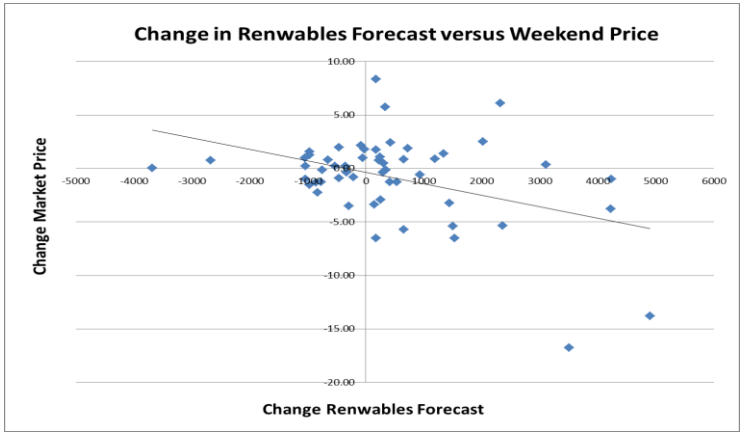
Method

- Price change versus expected average renewable production (solar, wind)
- Products: Week-Ahead and Weekend

Results

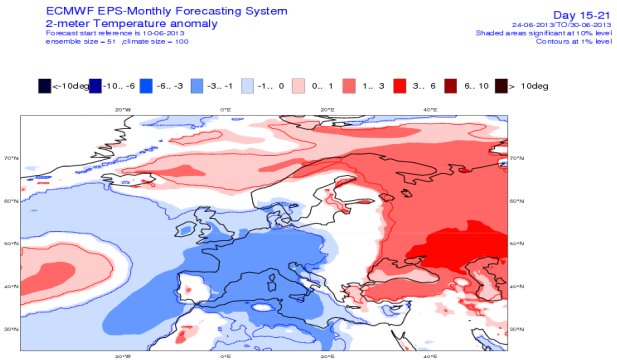
- Negative correlation between change in renewables and price
- A few outliers due to change of fuel prices
- If change in renewable greater than 2 GW, correlation perfectly negative

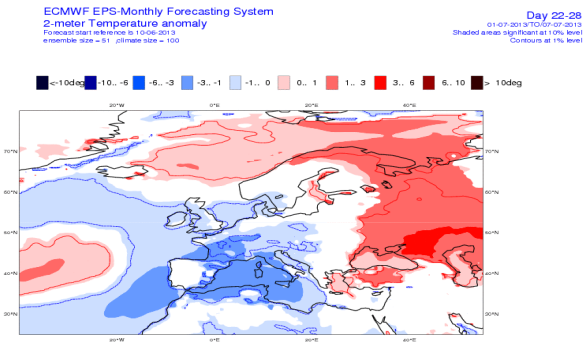


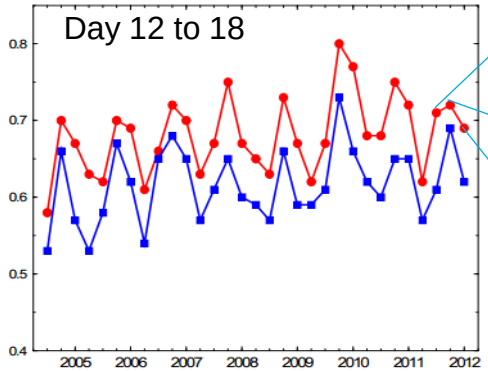


Sub-Seasonal ECMWF (28 day) ensemble predicition

> Shows some skill day 12 to 18. Can be cluster analyzed. Builds link to week ahead



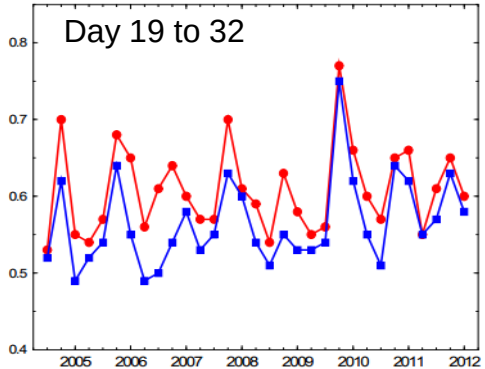




SON 11

DJF 11/12

MAM 12



Red: ROC curve (false positive/false alarm rate vs true positive rate) for the probability that 2m temperature is in the upper third of the climate distribution.

Source: ECMWF TechMem No. 688

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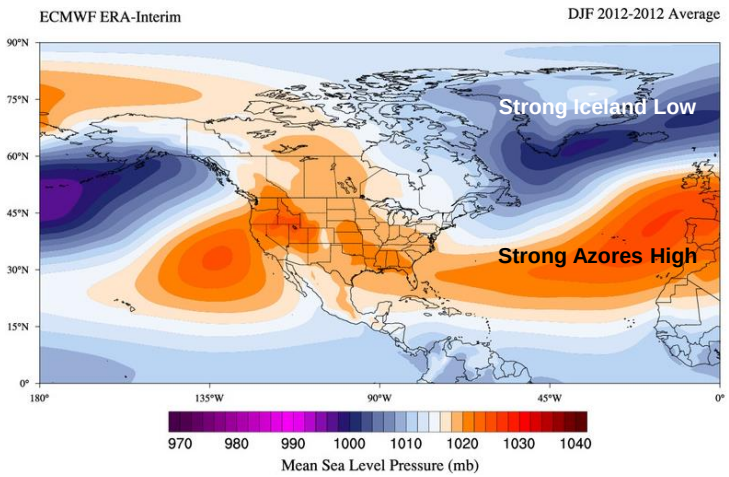
The North Atlantic Oscillation (NAO)

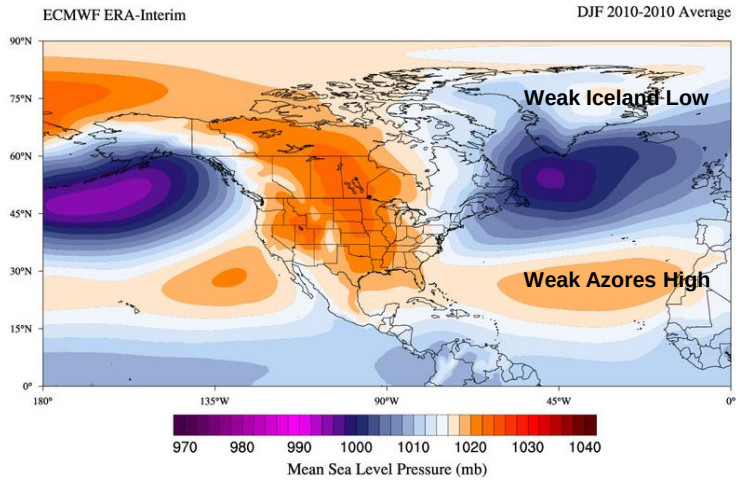
The North Atlantic Oscillation (NAO) index is based on the surface sea-level pressure difference between the Subtropical (Azores) High and the Subpolar (Iceland) Low.

The **positive phase** of the NAO reflects below-normal heights and pressure across the high latitudes of the North Atlantic and above-normal heights and pressure over the central North Atlantic, the eastern United States and western Europe.

The **negative phase** reflects an opposite pattern of height and pressure anomalies over these regions.



Winter 2011/12: DJF NAO = 1.37



Winter 2009/10: DJF NAO = -1.67

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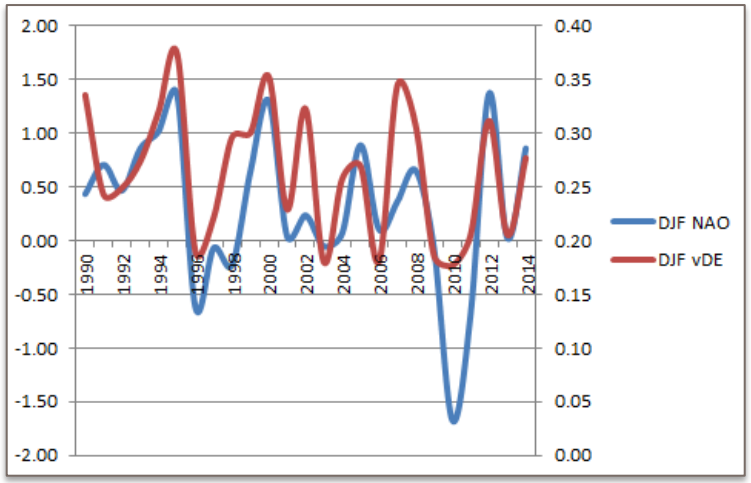
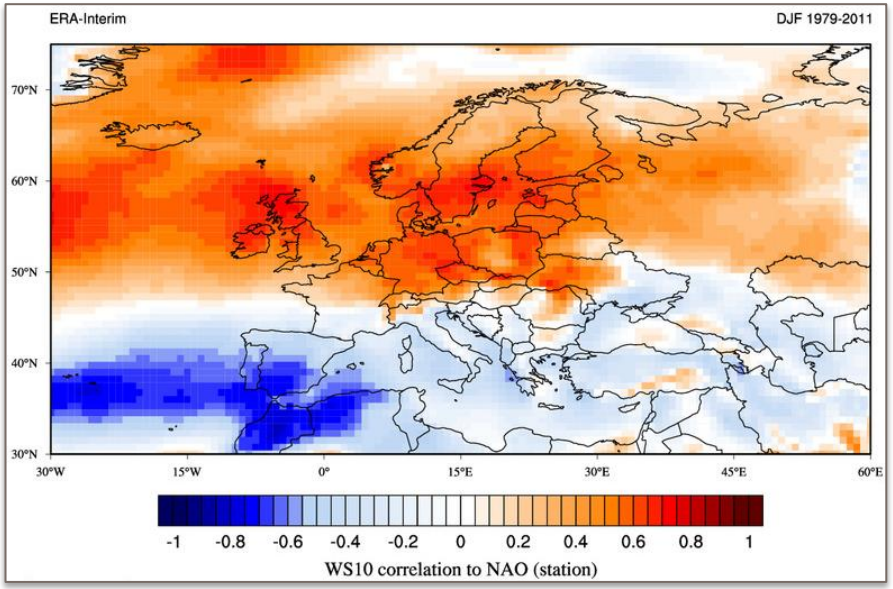
The North Atlantic Oscillation (NAO)

Comparison between German winter (DJF) wind power generation (here the average load factor) and the state of the winter NAO index shows a good correlation between the two elements of r2 = 0.72, based on observations from 1990 to 2014.





The positive correlation is similar or better for almost all N European wind generating areas, e.g. UK, Danmark, the North Sea & Sweden, while the S od Spain is strongly negative correlating

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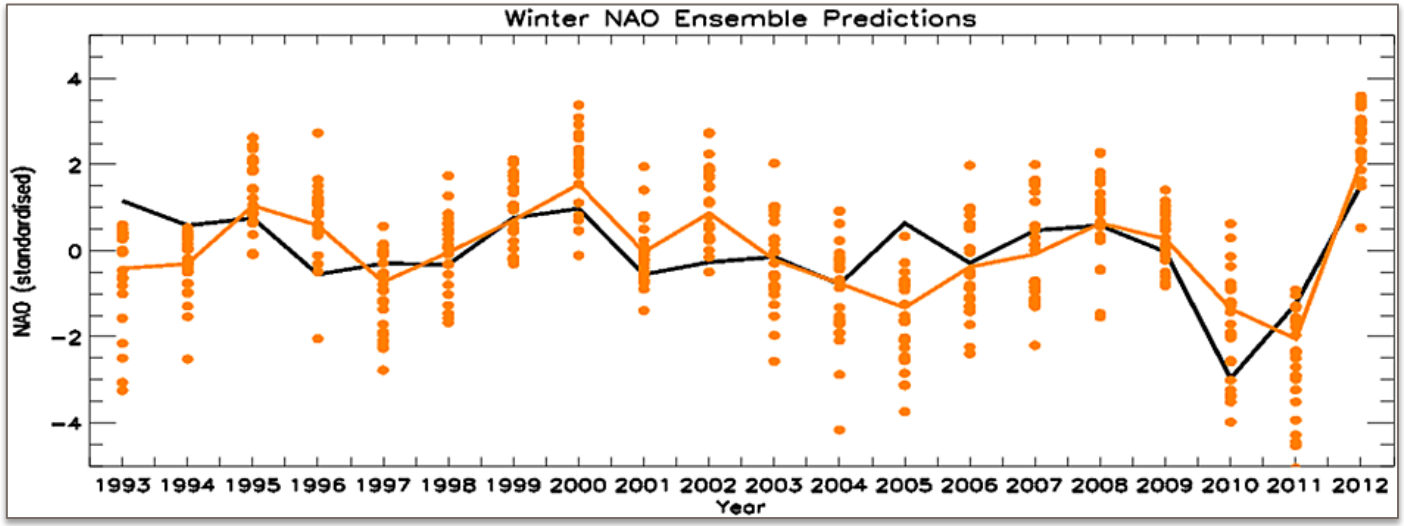
The North Atlantic Oscillation (NAO)

So, what if we knew the NAO for the upcoming winter? Some research groups claim to have a good forecast based on the predictability of other teleconnection patterns, such as the N Atlantic subpolar gyre (salinity ice melt), the Kara Sea Ice concentration, the Eurasian snow cover, the QBO and ENSO ONI.

The correlation score of 0.62 is significant at the 99% level according to a *t* test and allowing for the small lagged autocorrelation in forecasts and observations.



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Viking Law:

Weather & Renewables are your competitive edge!

TAKK

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