Wind Energy

Valuation and Risk Management

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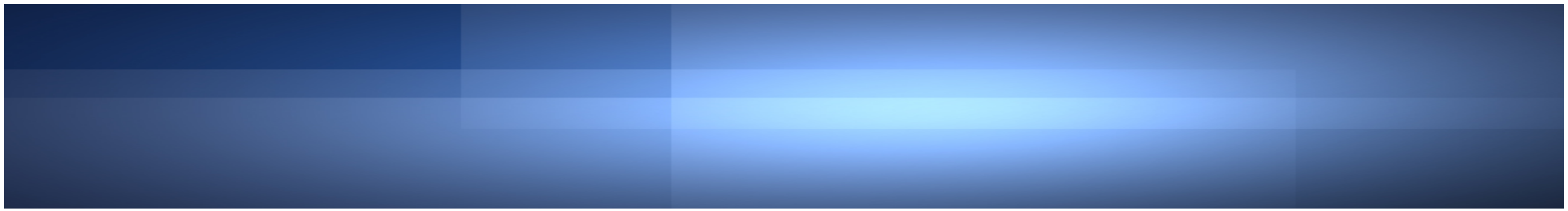
The importance of Risk Management

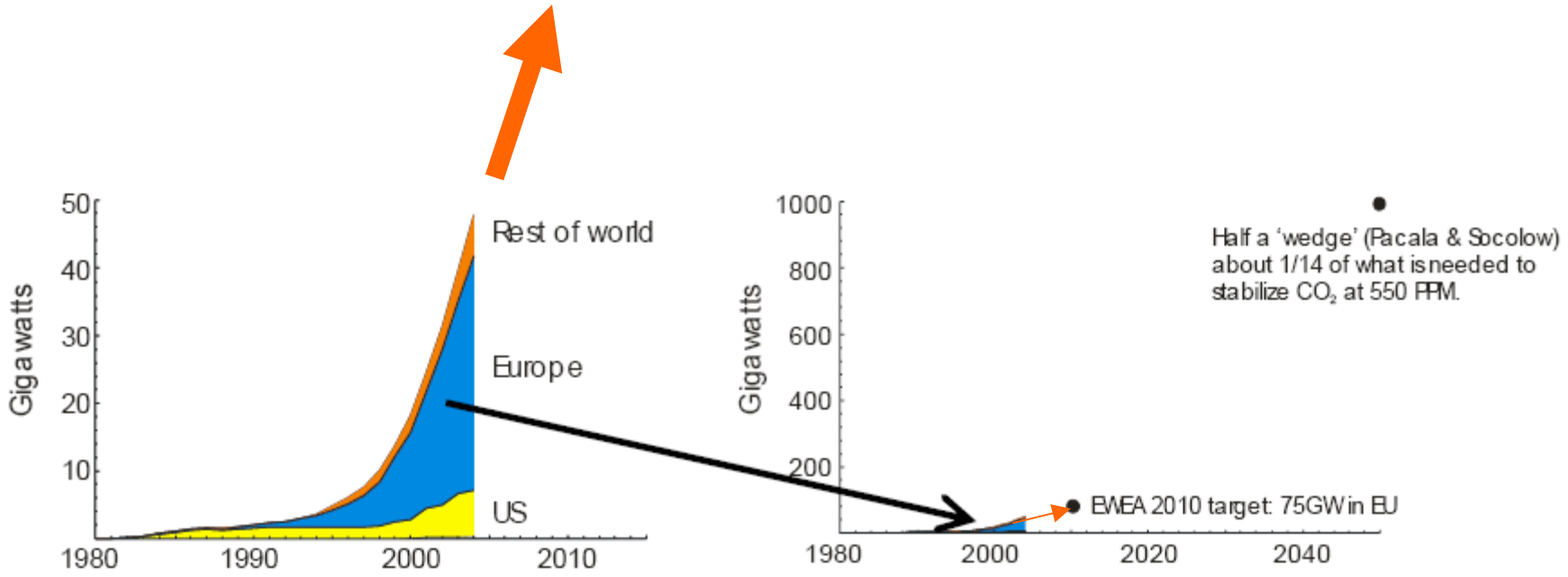
A wind turbine cost
800.000 Euro/MW
Currently install rate:
8.000MW / year (Europe)

Investing 6+ Billion Euro **per year**

..all of it exposed to -and interacting with- volatile power prices



The Wind Energy Market: What's going on?



50.000MW Installed capacity in Europe (2006)

8.000MW growth per year

Some Questions to Ask

Investment decision (before building):

- Will it be profitable?
- What is the risk of going bankrupt?

Operational issues (day-to-day):

- How electricity will I produce in the (near) future?
- What transactions can I do to reduce risk or increase revenues?

Main Points in This Presentation

An overview of modeling and risk management techniques

1. How to Model Wind Speed
2. Converting Wind to Electricity
3. Converting Electricity to Money
4. Reducing Risk strategies

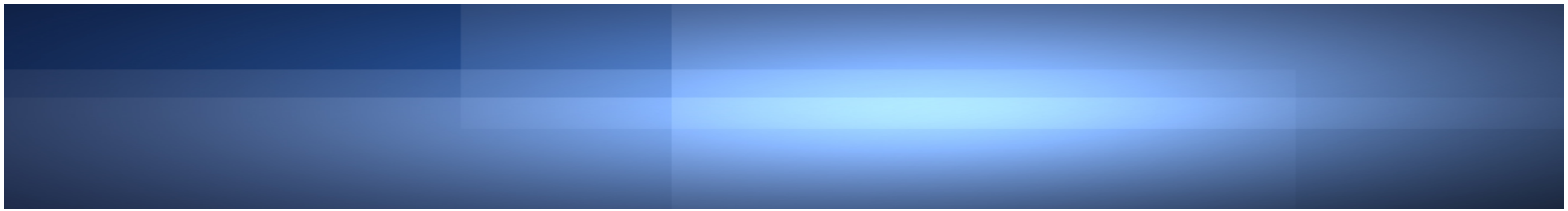
Typical Application

- Estimate future electricity production
- Estimate future revenues
- Estimate the risk & hedging methods

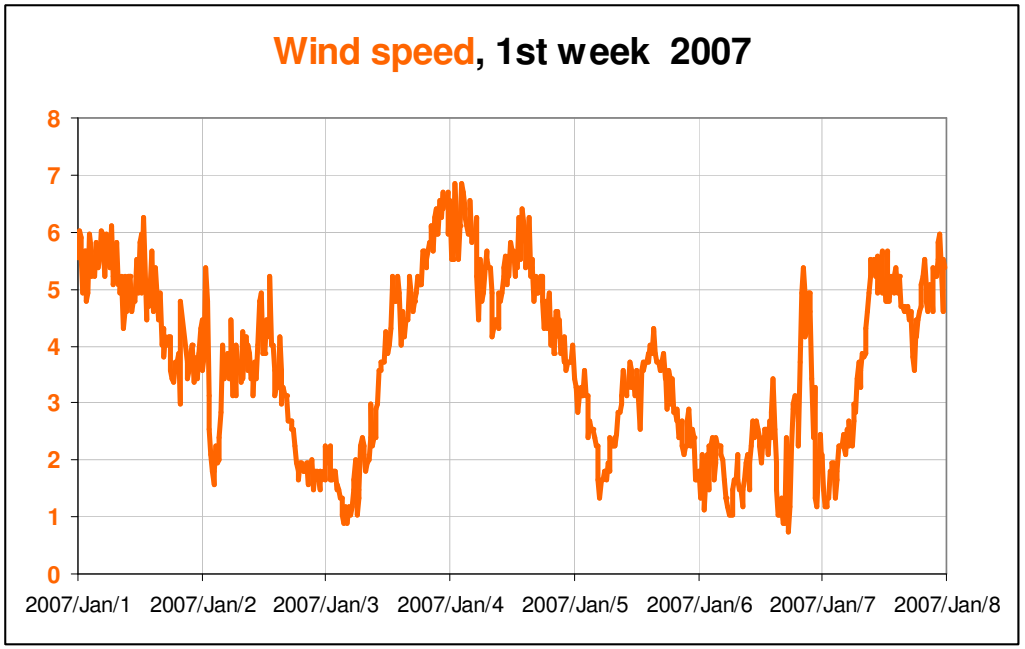
Modeling Wind Speed

Wind Speed

Wind speed is the most important factor in estimating wind electricity production



Modeling Wind Speed



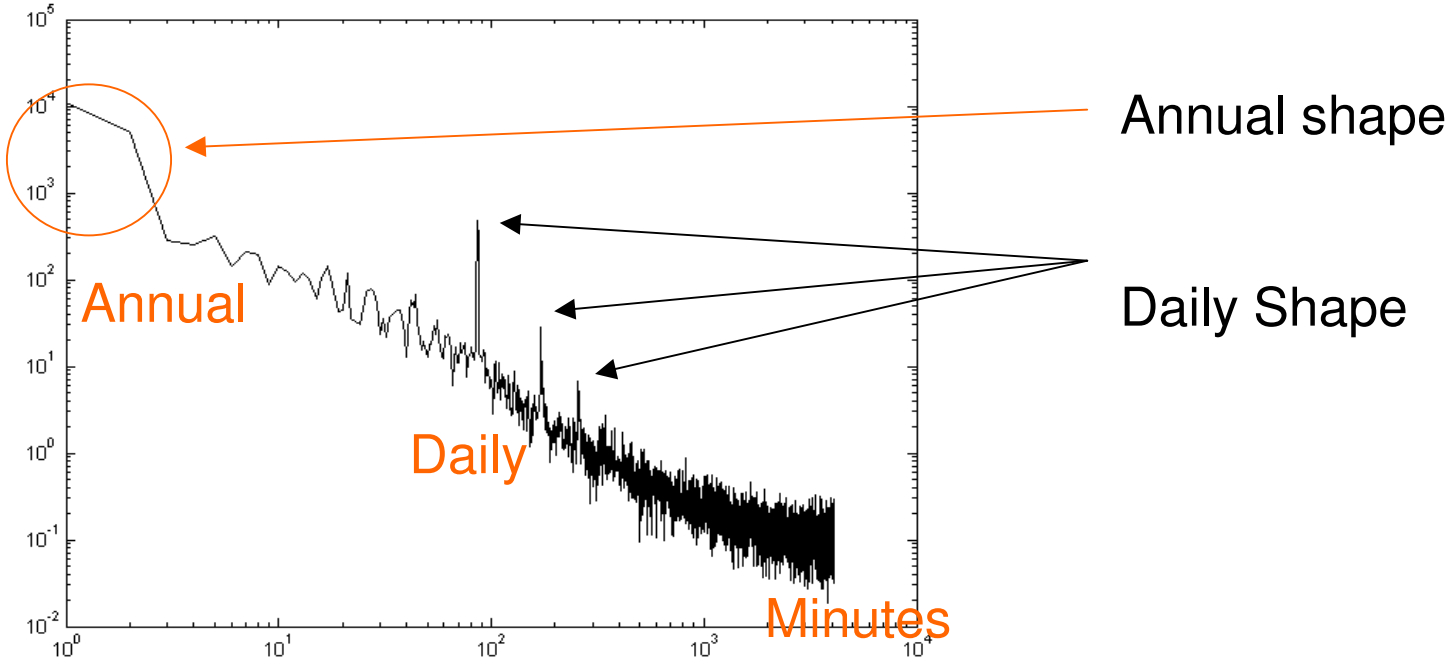
Example of 15 minute average wind speed at Flevoland, first week of 2007

Applications:

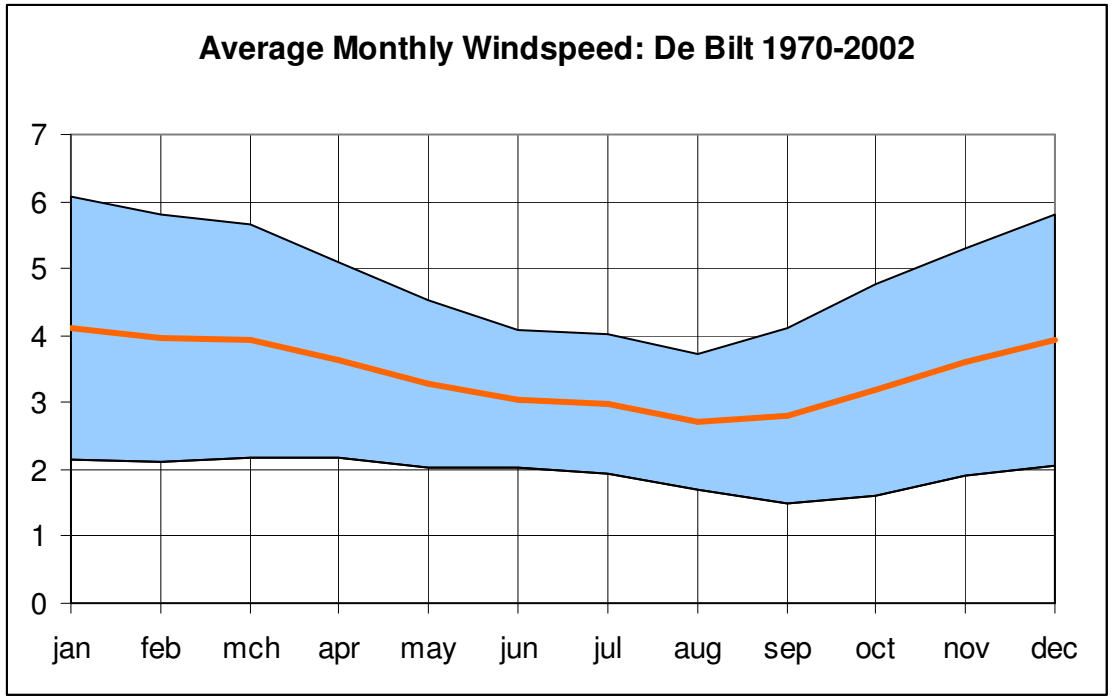
- Random wind speed scenarios for Monte Carlo methods
- Short term wind forecast

Wind speed Power Spectrum

The power spectrum reveals a lot of information about the behavior of wind speed at different time-scales



Wind Speed has an Annual Shape



Based on daily average wind speeds measured in De Bilt in the period 1970-2006

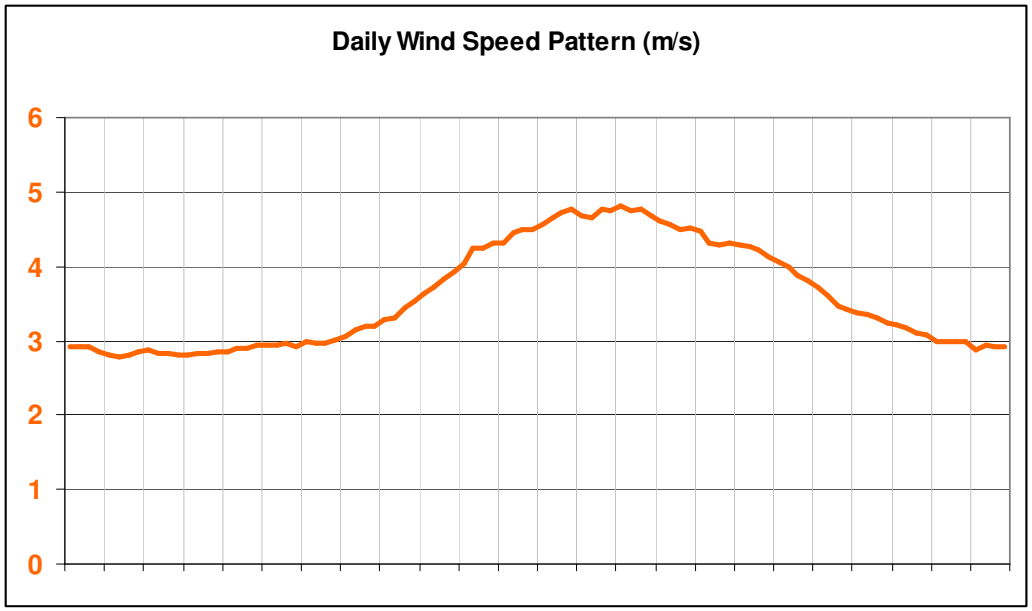
Observe:

- Seasonal Shape
- Seasonal Variance

Known properties:

- Location Dependent
- Height dependent

Wind Speed has a Daily Shape



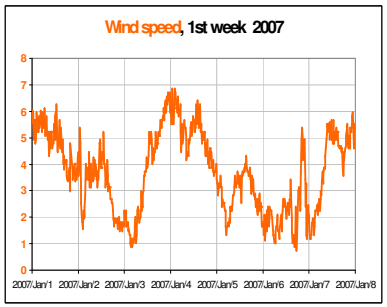
Based on 1 year of 5 minute wind speed measurements the period 2007 at Flevoland

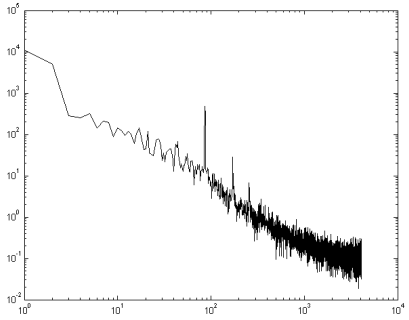
- Strongest winds in the afternoon
- Shape depends on surface type

Modeling Dynamical Noise

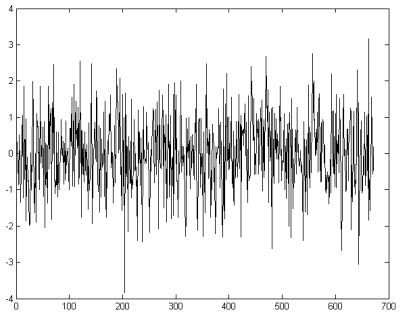
Does any of these well-known models fit?

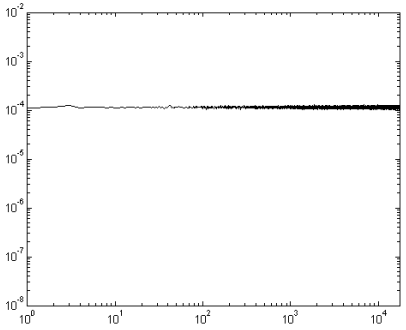
Wind speed



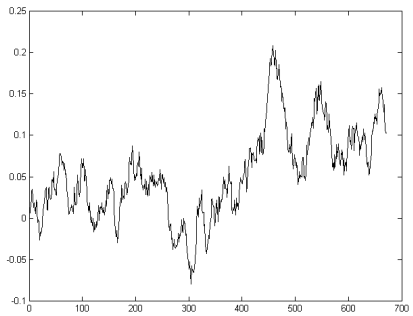


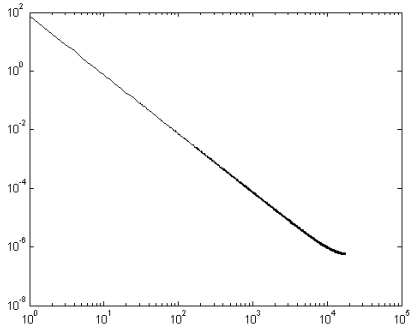
White noise



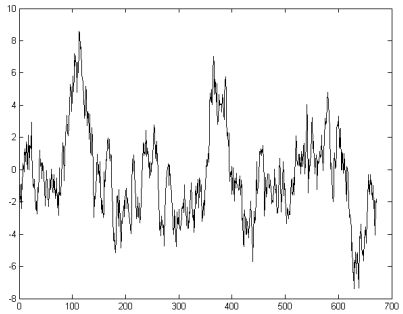


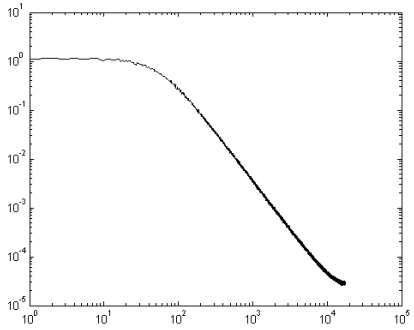
Brownian Motion





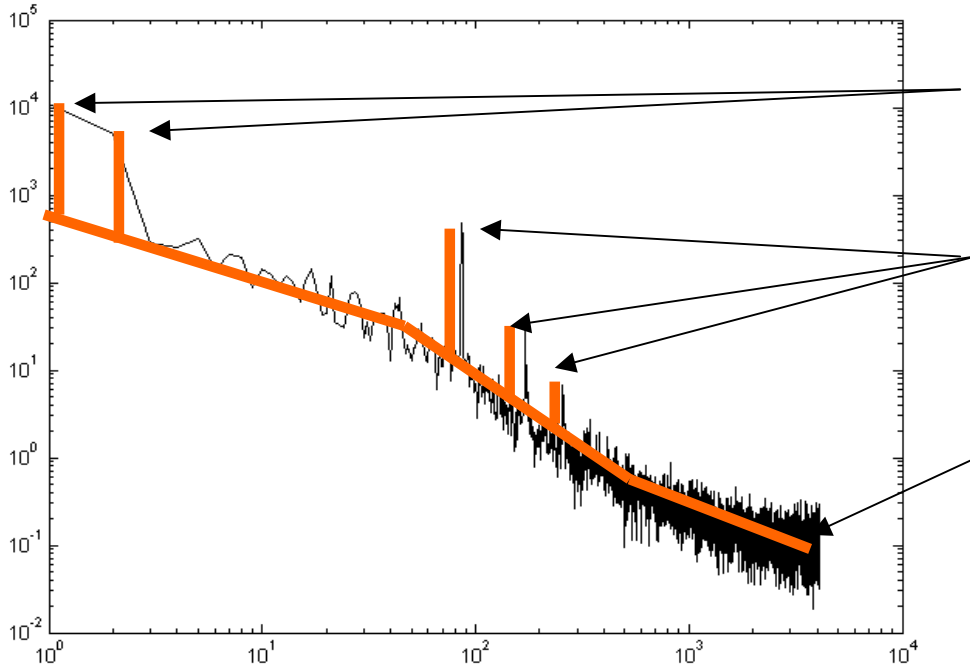
Mean reverting





Wind Speed Behavior

A good dynamic wind speed model will have a mix of properties



Seasonal shape

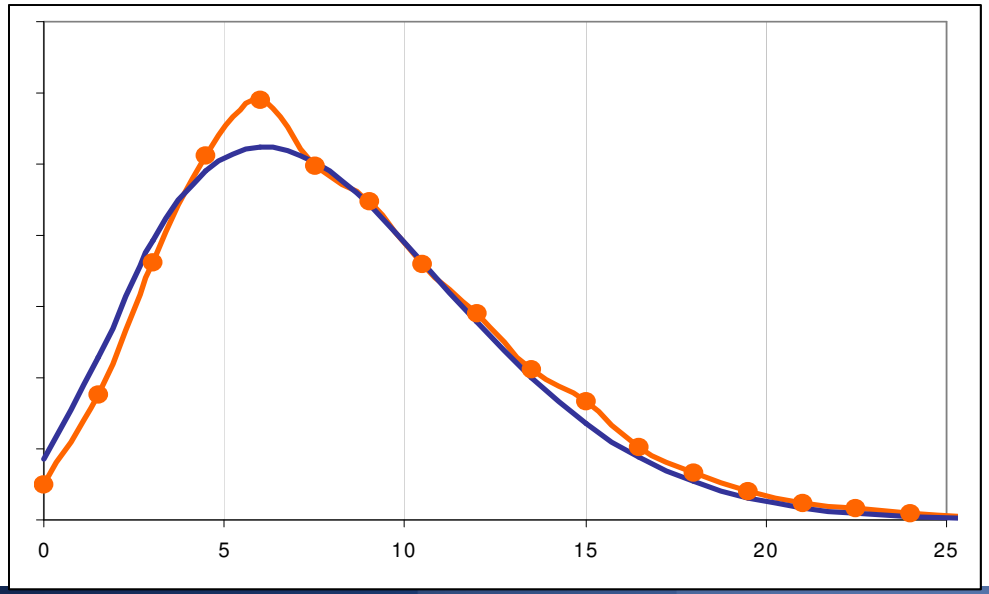
Daily shape

Timescale dependent noise level

Hourly Wind Speed Probabilities

When not interested in the time dynamics of wind speed:

A good model of probabilities is the **Weibull distribution**



Weibull distribution

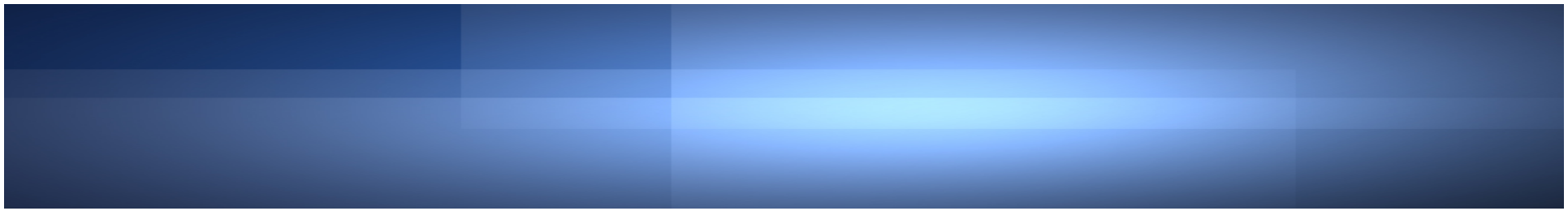
$$f(x;k,\lambda) = \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-(x/\lambda)^k}$$

shape parameter k +/- 2.0

mean = $\lambda\Gamma\left(1+\frac{1}{k}\right)$

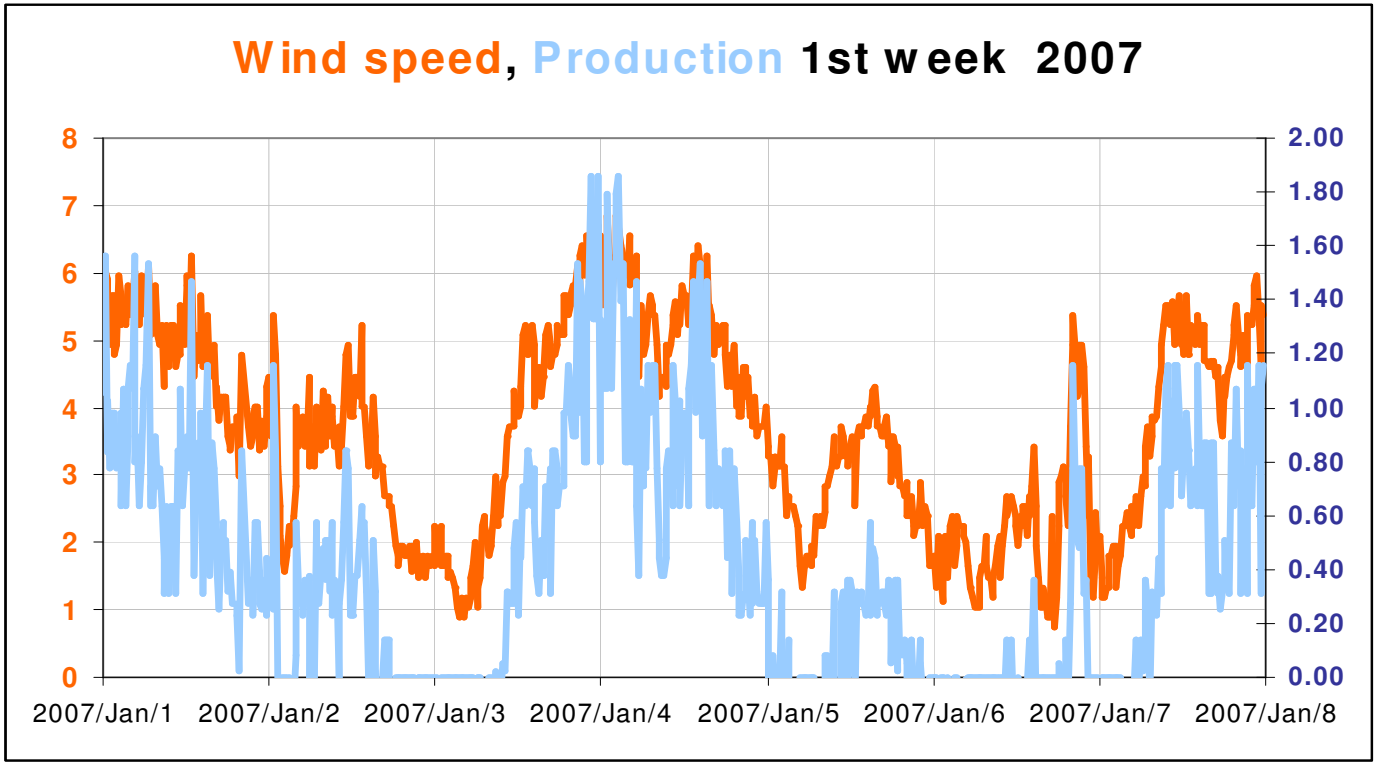
Conclusion about Wind Speed Modeling

- Seasonal Shape
- Daily Shape
- Mean reversion
- Time scale dependent noise behavior
- Non conventional probability distribution



Converting Wind speed into Electricity

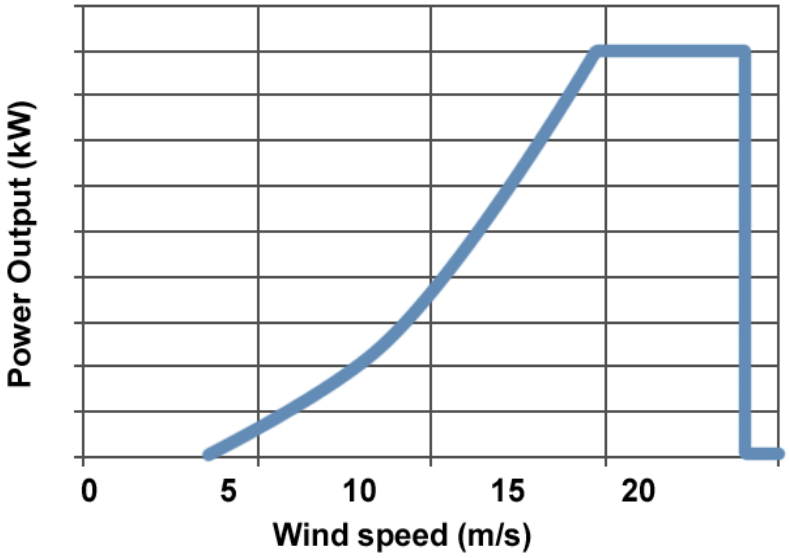
From Wind speed to Electricity production

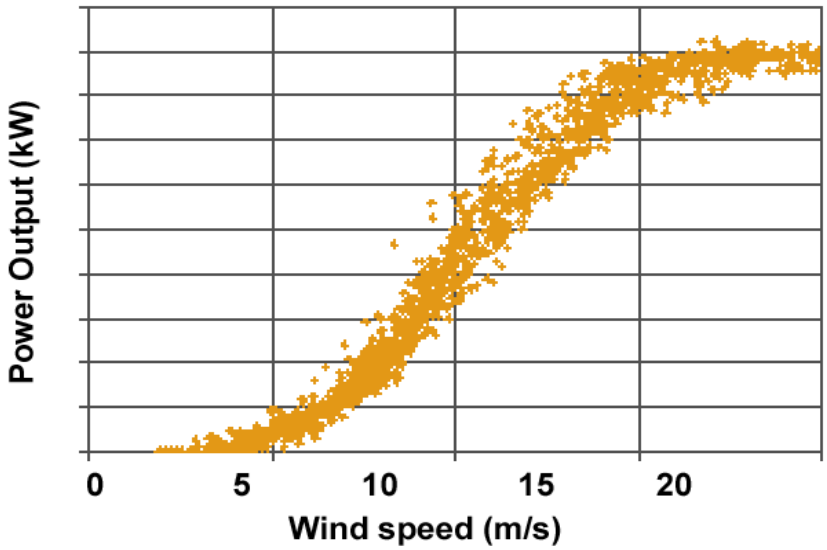


A wind turbine needs a minimum amount of wind

Relation Wind speed & Electricity Production
The Power Curve

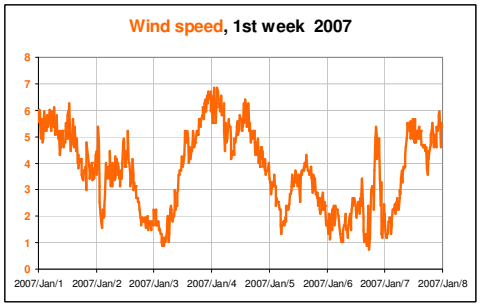
The amount of power produced as a function of wind speed





Production Forecast

Production forecast

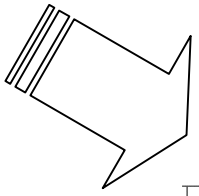


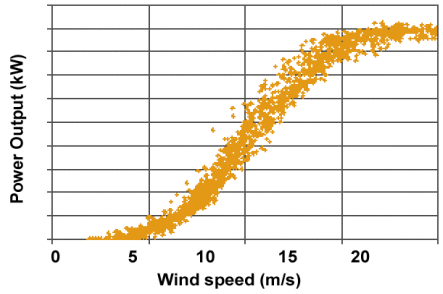
Model wind speed

- mean reverting model
- regression model

or

Buy wind forecasts





Convert wind speed to production

Be aware when buying forecasts:

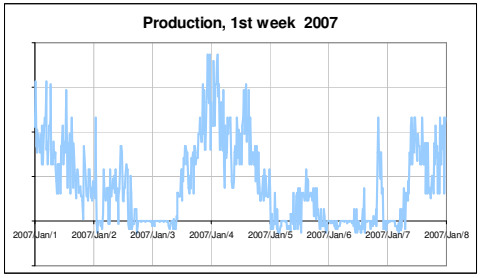
- Don't use expected/average future wind speed to obtain expected electricity production
- Use future wind speed probability distribution instead

Wind	Probability	Power curve
1	1/6	0
2	1/6	0
3	1/6	20
4	1/6	20
5	1/6	20
6	1/6	0

Average wind 3.5

Short term production forecast

Needed when you have a wind turbine, ...for trading short term markets, ...for the grid operator



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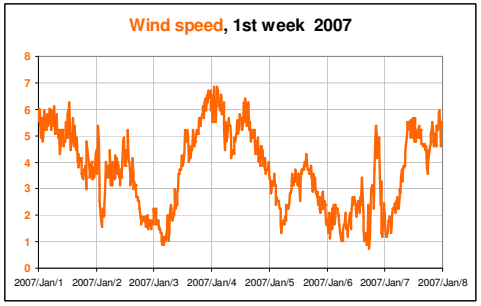
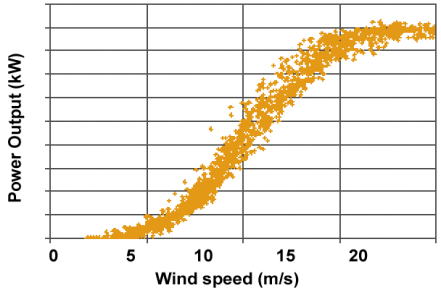


Include real time production data.

Your turbine is a (a rather big) wind speed meter



Convert wind speed to production

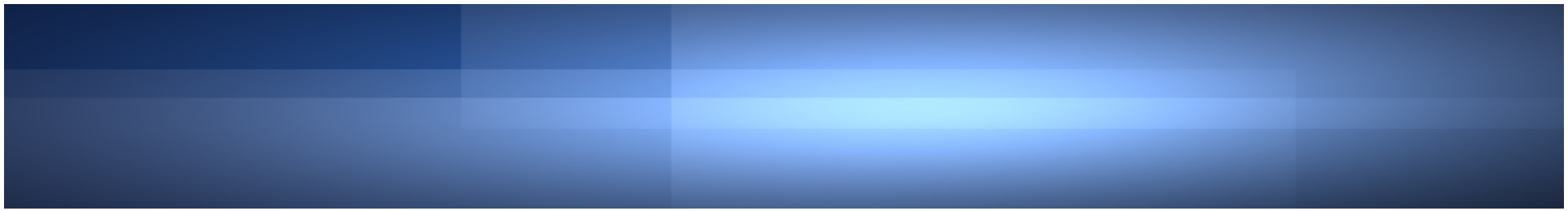
Electricity Revenues & Risk

Selling the Electricity

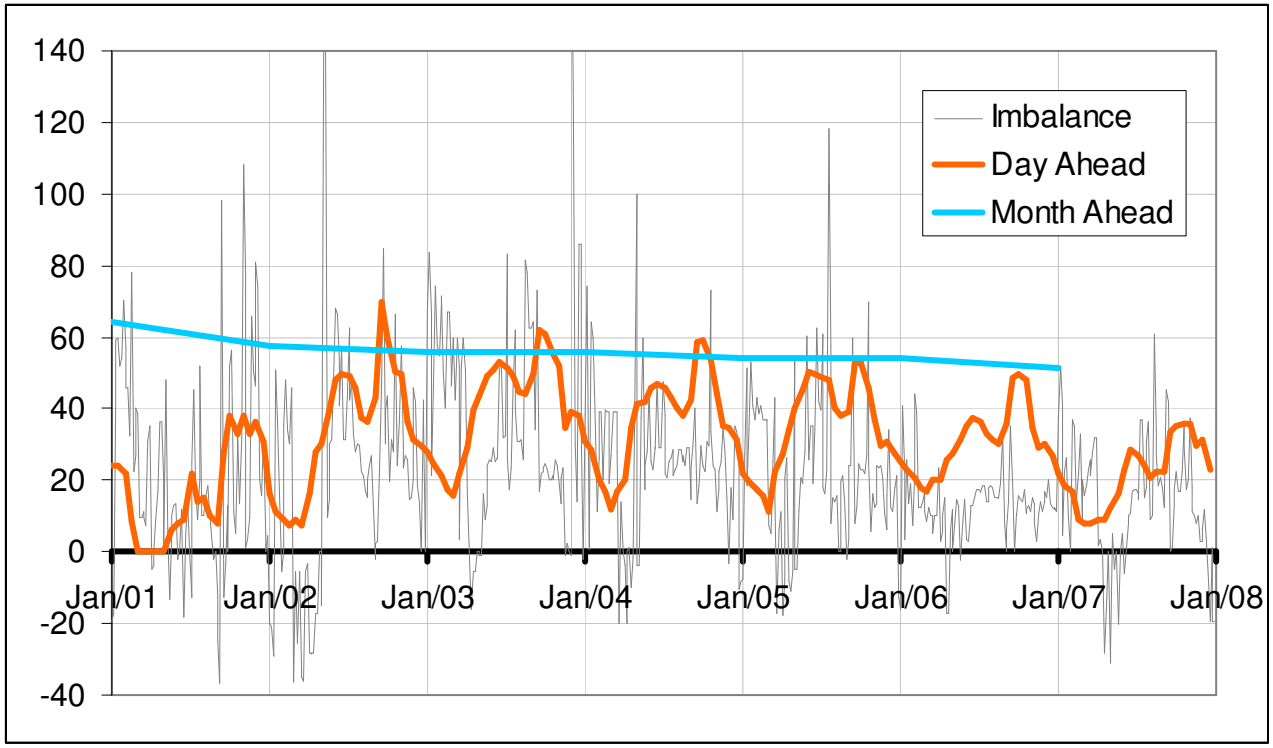
1. Imbalance market (TenneT)
    - A real time price for electricity

2. Day ahead market (APX)
    - Buy and sell electricity for individual hours for the next day

3. Forward Market (OTC / ENDEX)
    - Annual, quarter and month block for the next couple of years



Volatility of the different Markets



Dutch electricity prices in the first week of 2007; source tenner.org, apxgroup.com, endex.nl

Imbalance market is very unpredictable

Forward Markets (month ahead) are much more stable

Sell Strategy 1: Sell ALL electricity to Imbalance market

Might not be a good idea:

- The imbalance market is the most volatile market resulting in the most uncertain revenues, RISK

- The imbalance market prices has negative correlation with wind production volumes

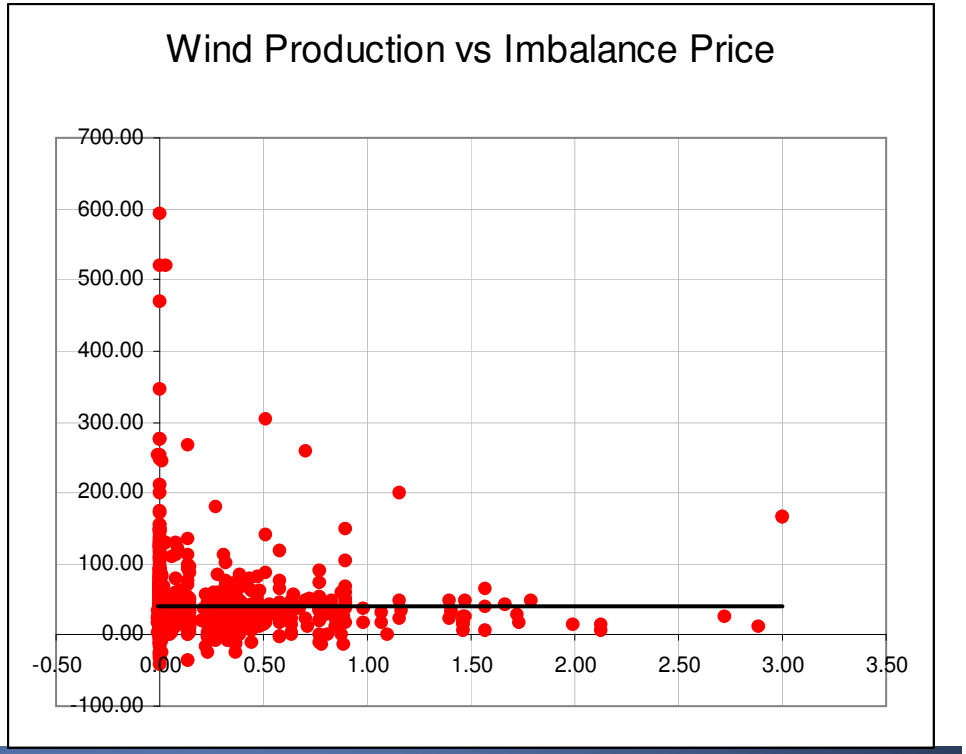
“The negative correlated imbalance prices”

Don’t assume linear correlation!

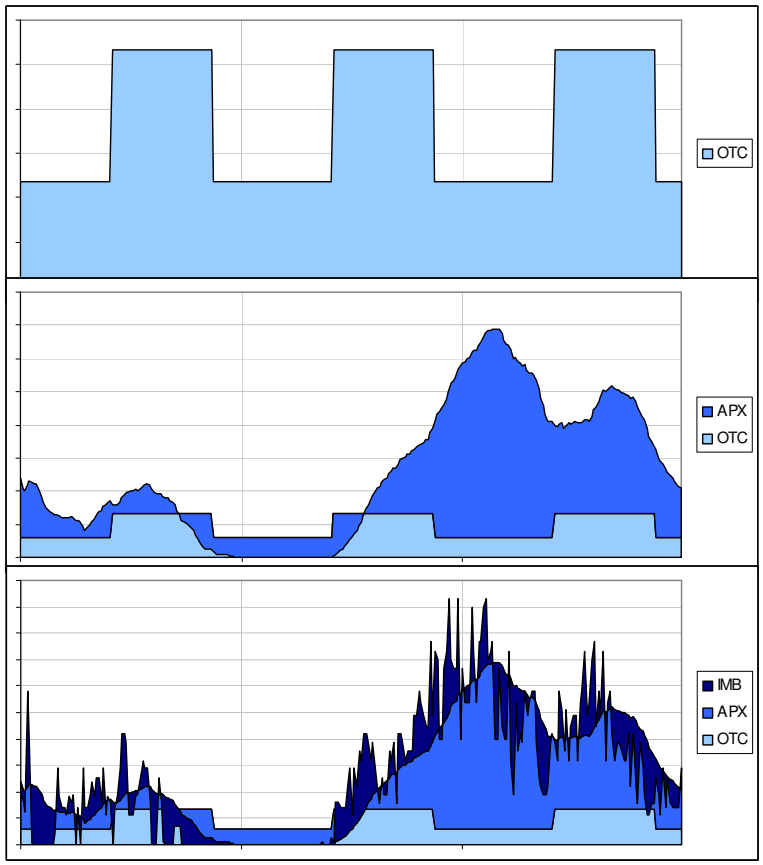
A good method, compare:

1. selling a constant volume on the imbalance market with
2. selling the same volume, but more when its’ windy, and less when not

Average 2007 imbalance price	37.73 €/MWh
Average 2007 Revenues	34.63 €/MWh
Selling wind production vs Baseload	**-13%**



Sell Strategy 2: Multiple Markets

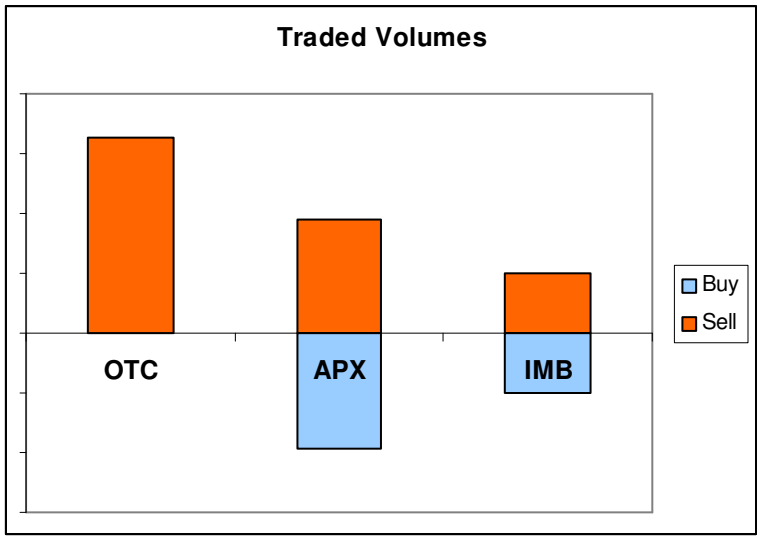


Sell long term volume to the OTC market

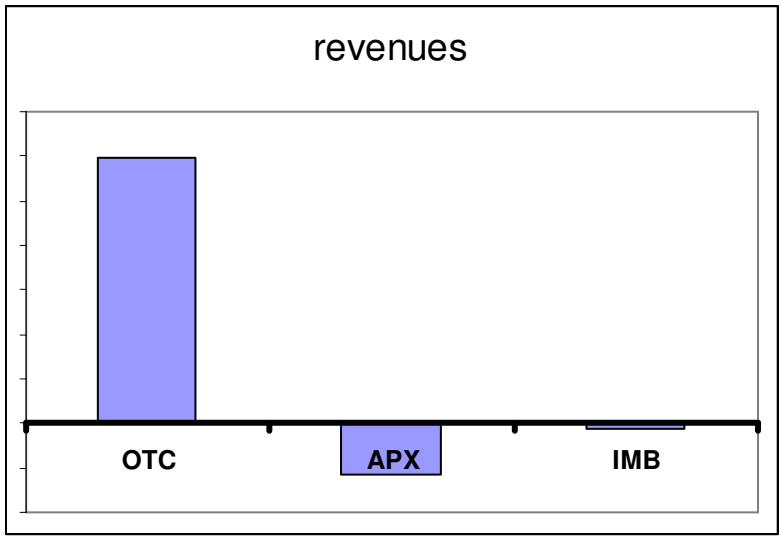
Adjust to day ahead production forecast on the APX

Buy/Sell the day ahead forecast error on the Imbalance market

Sell Strategy 2: Traded Volumes

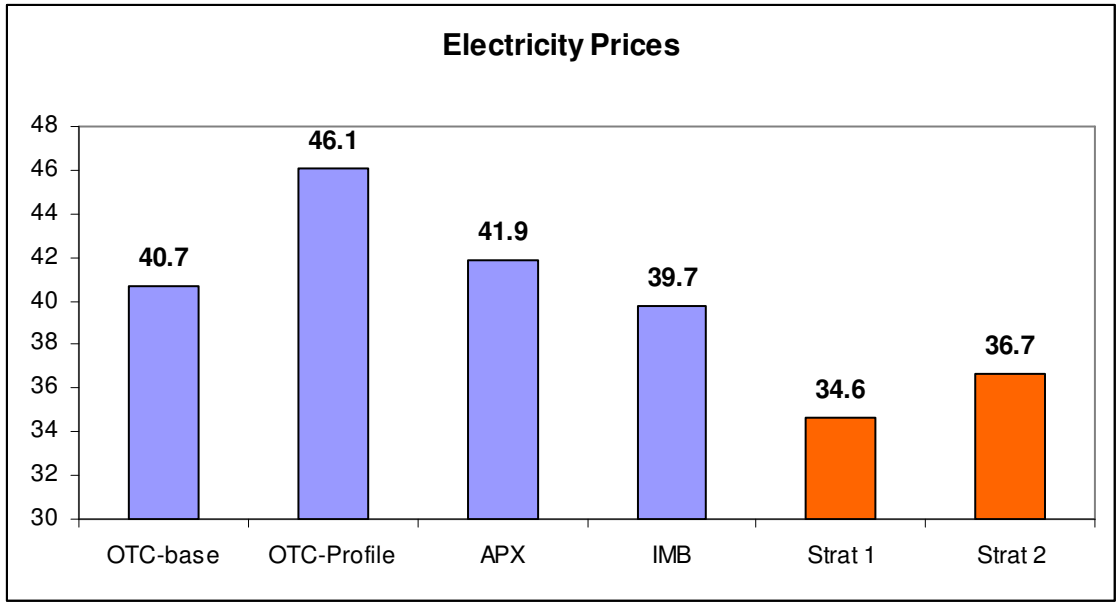


More trading, and less exposure to APX and IMB market



Most of the revenues are linked to OTC

Comparison of prices



Wind revenues are below average market price

Selling on multiple market has financial benefits

Selling on multiple markets has risk benefits

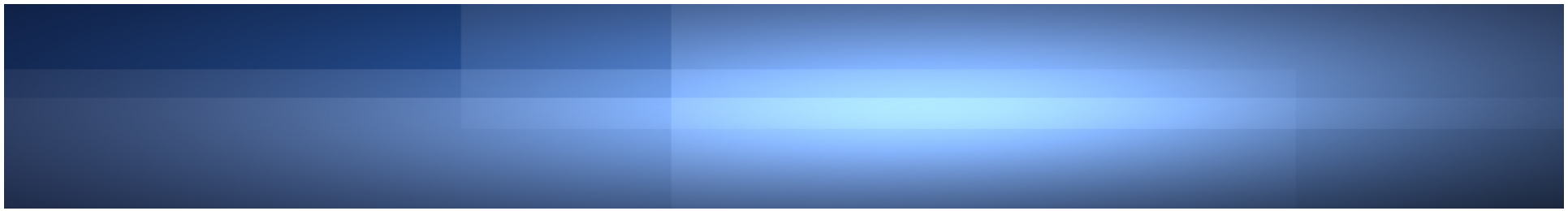
Beyond the Tradable Markets

How to limit the risk of price movements **for the next 20 years**?

- Only the first few years can be hedges (3 years). The price in the remaining years might go down

Hedge Strategy:

- Sell something that's strongly correlated with the value of the 17 remaining years!
- When prices go down, buy it back with a profit, which will compensate the loss of electricity revenues



Hedging Beyond the Tradable Markets

Two typical hedging approached:

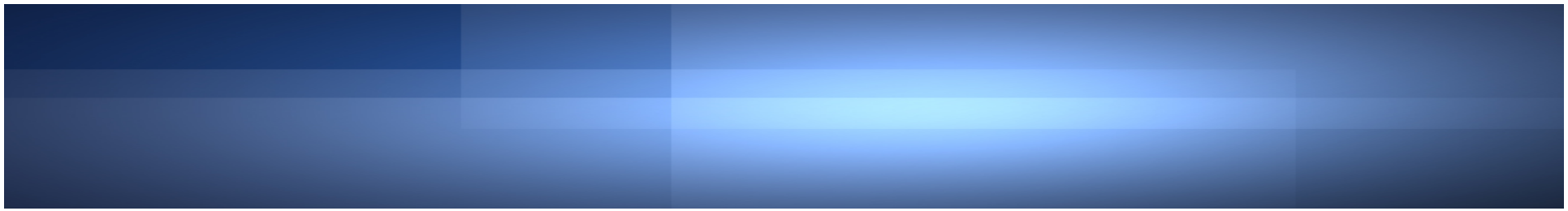
1) Fuel prices

- *Electricity prices are functions of the fuel price. Some fuel prices allow for long term trading. Sell a basket of fuel*

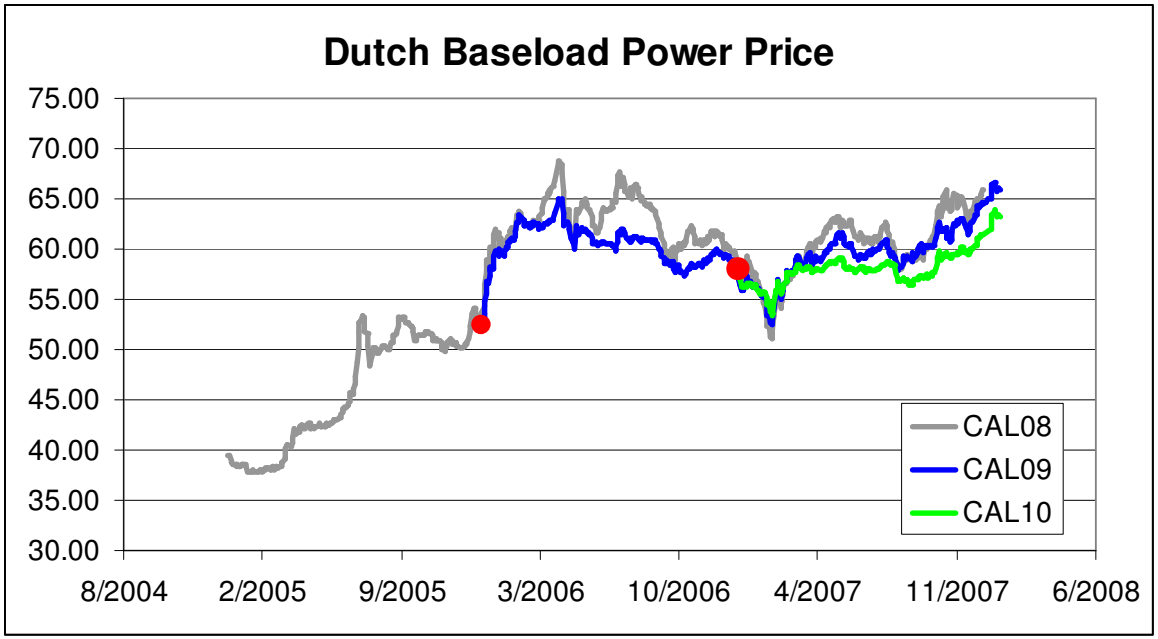
2) Stacking the curve

- Correlation assumtion: If prices for next year go up/down, so will prices for the following year.
- Empirical Evidence supports this

We focus on this

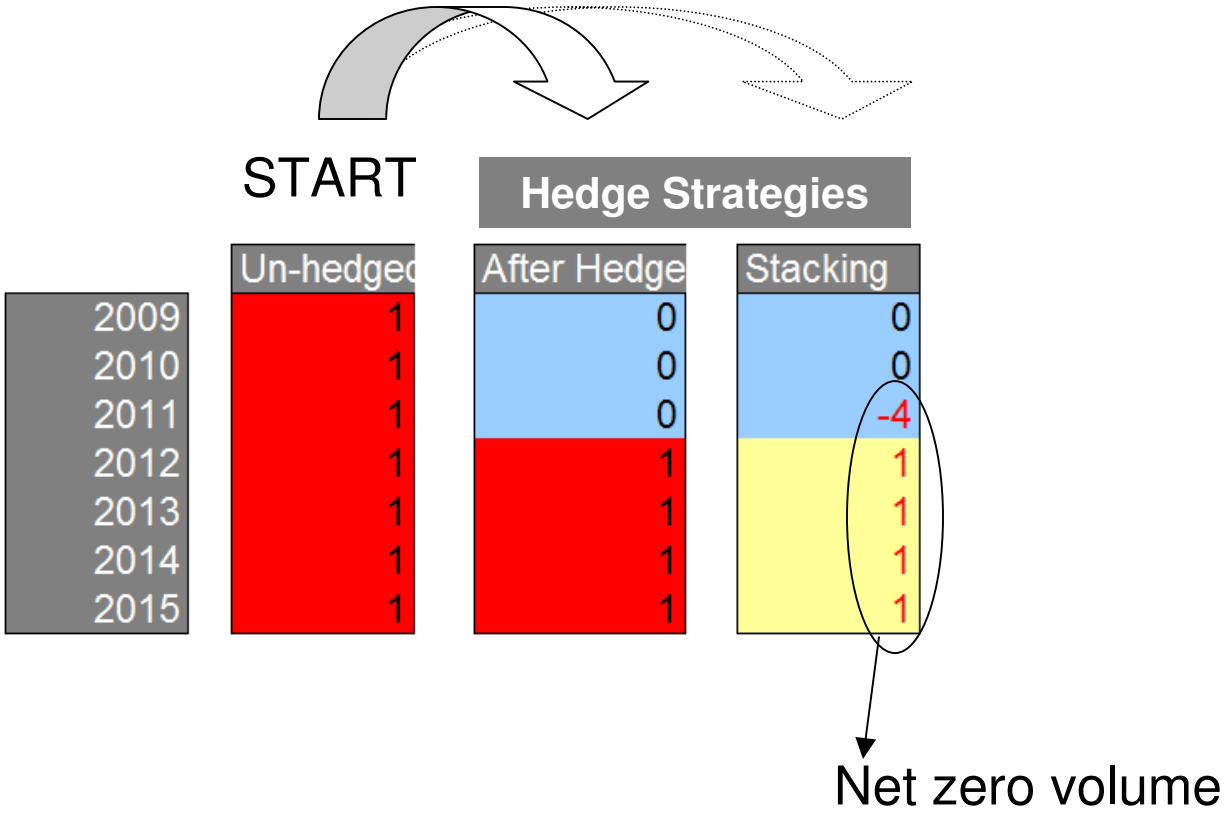


Hedging Beyond Tradable Markets : Stacking



Assume that far future power prices movement correlate well with nearby future power prices movement

Hedging Beyond Tradable Markets : Stacking

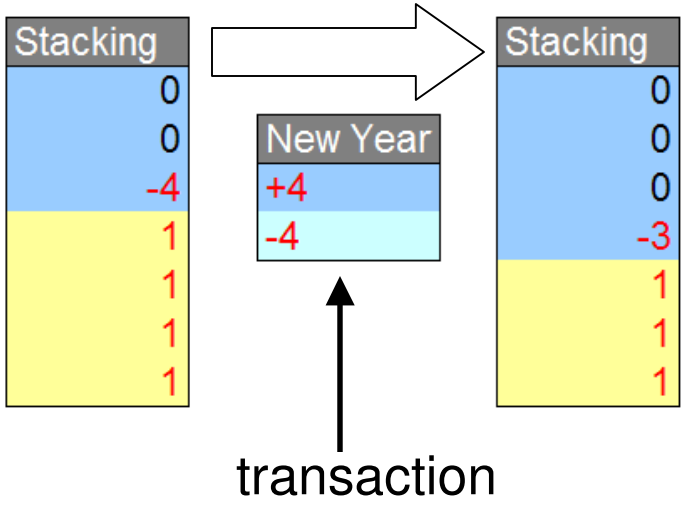


Hedging Beyond Tradable Markets : Stacking

2009
2010
2011
2012
2013
2014
2015

As years go by...

Roll over to next year, reducing the "number of spreads"



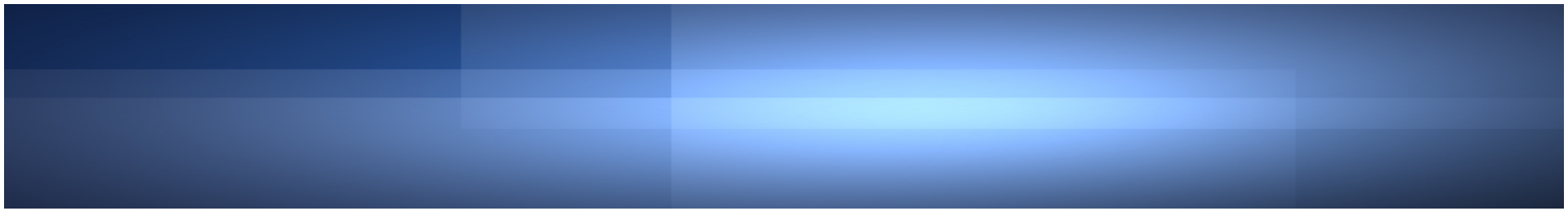
Hedging Beyond Tradable Markets : Stacking

Benefits of stacking

- Risk reduction of a factor 2-6
- Market to Market

Drawbacks of stacking

- Much more trading activity causes buy-sell losses
- Cash flow position



thank you!

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