# Review of types of electricity price models used in practice by a power utility

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# Plan

1. Motivations and context
2. Price models
3. Conclusions

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1. Motivations and context
   - Motivations
   - Price caractheristics
2. Price models
3. Conclusions

# Commodity modeling for an energy company : objectives

Short term (1 day $\rightarrow$ 2 weeks) prediction

Market understanding

Mid term risk management

- Gross energy margin prediction
- Risk measurement
- Hedging

Pricing

- Valuation of Production assets
- Valuation of flexibilities in supply contracts

Physical portfolio management

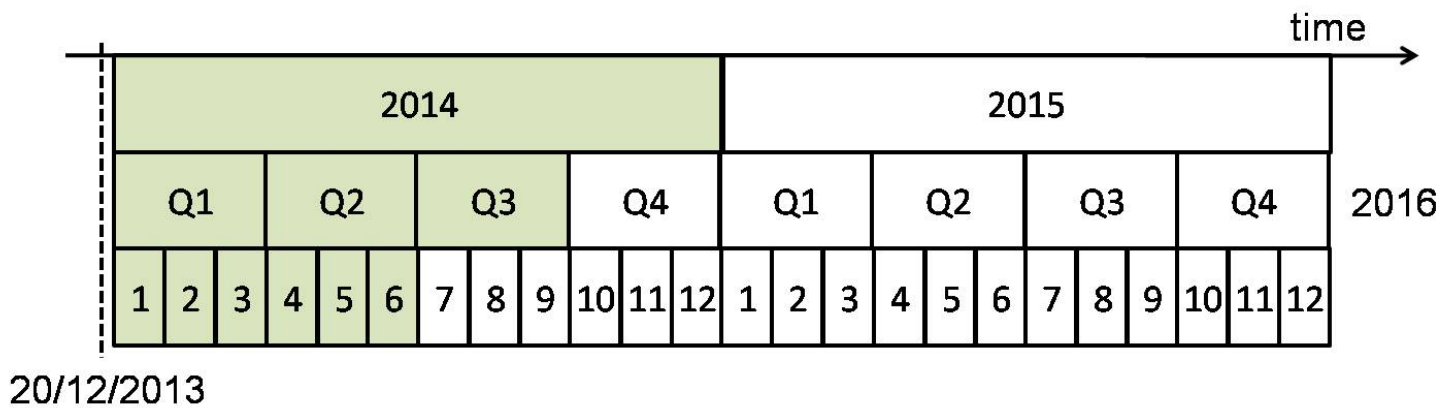
- Physical assets management
- Fuel stocks management

Investment decision

# Non storable you said ?

As power is non storable, hedging is performed using forward products.
Example of forward products available on EEX for Germany/Austria :

- intraday (hour and quarter), day (hour)
- weekend, current week and next 4 weeks,
- current month and next 9 months,
- next 11 quarters, next 6 years



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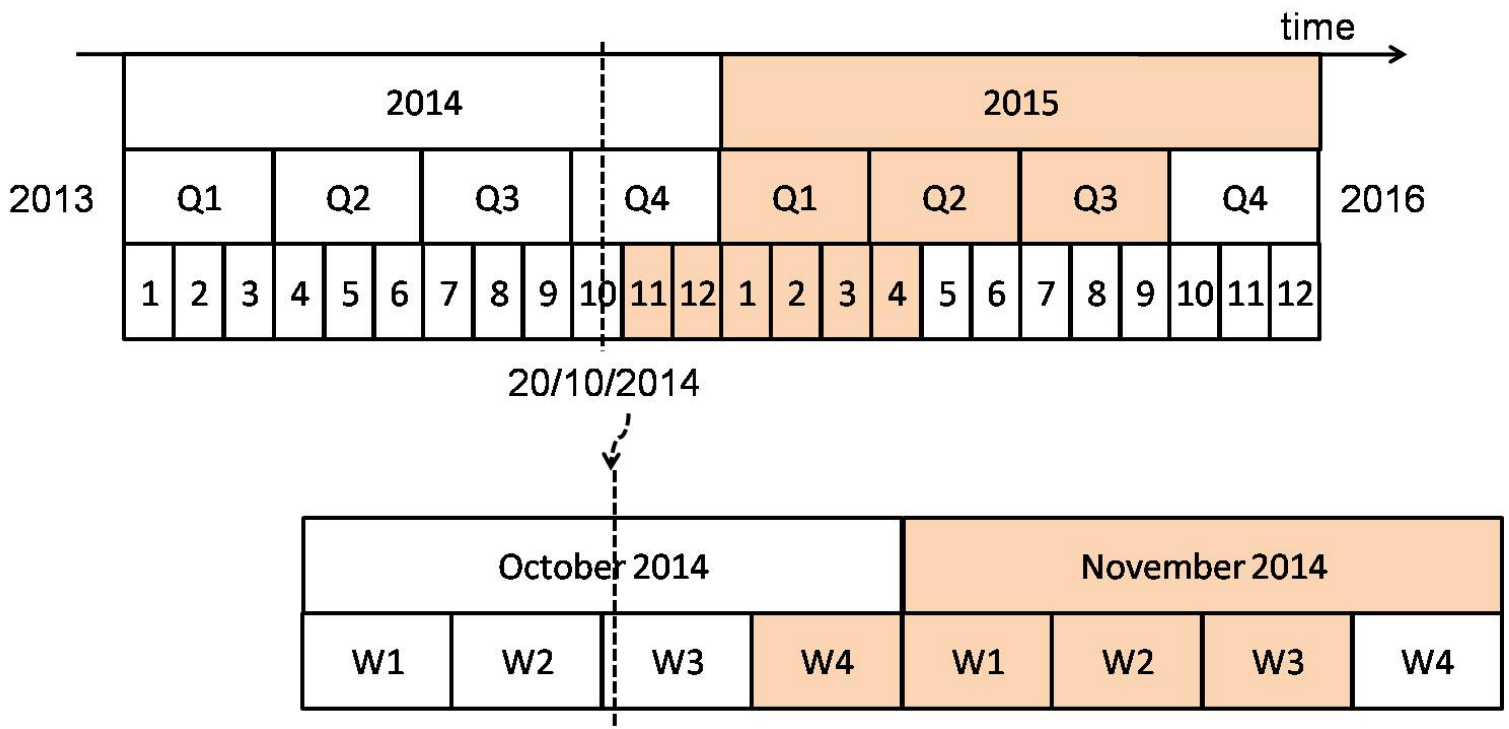
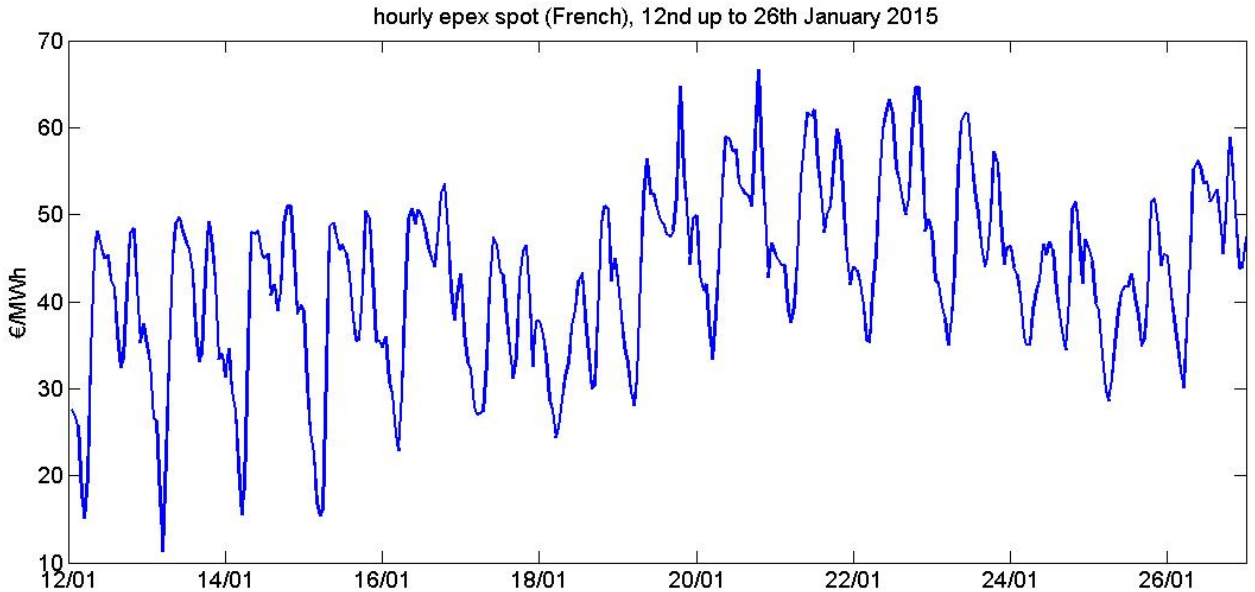


# Seasonnality

Power prices have a strong seasonal pattern : daily, weekly and yearly seasonnality




A misspecification of the long term seasonal curve can introduce bias or artificial price variability (for illustration see [Weron (2014)])

A benchmark in EDF shows that for a strip of at-the-money monthly options, different seasonnality hypotheses (all coherent with practionners methodologies) represent up to 20% of the value.

# Link between commodities

The evolutions of power and commodities prices are closely linked. Power companies portfolio are exposed to all these prices and modelling accurately these dependencies is challenging.

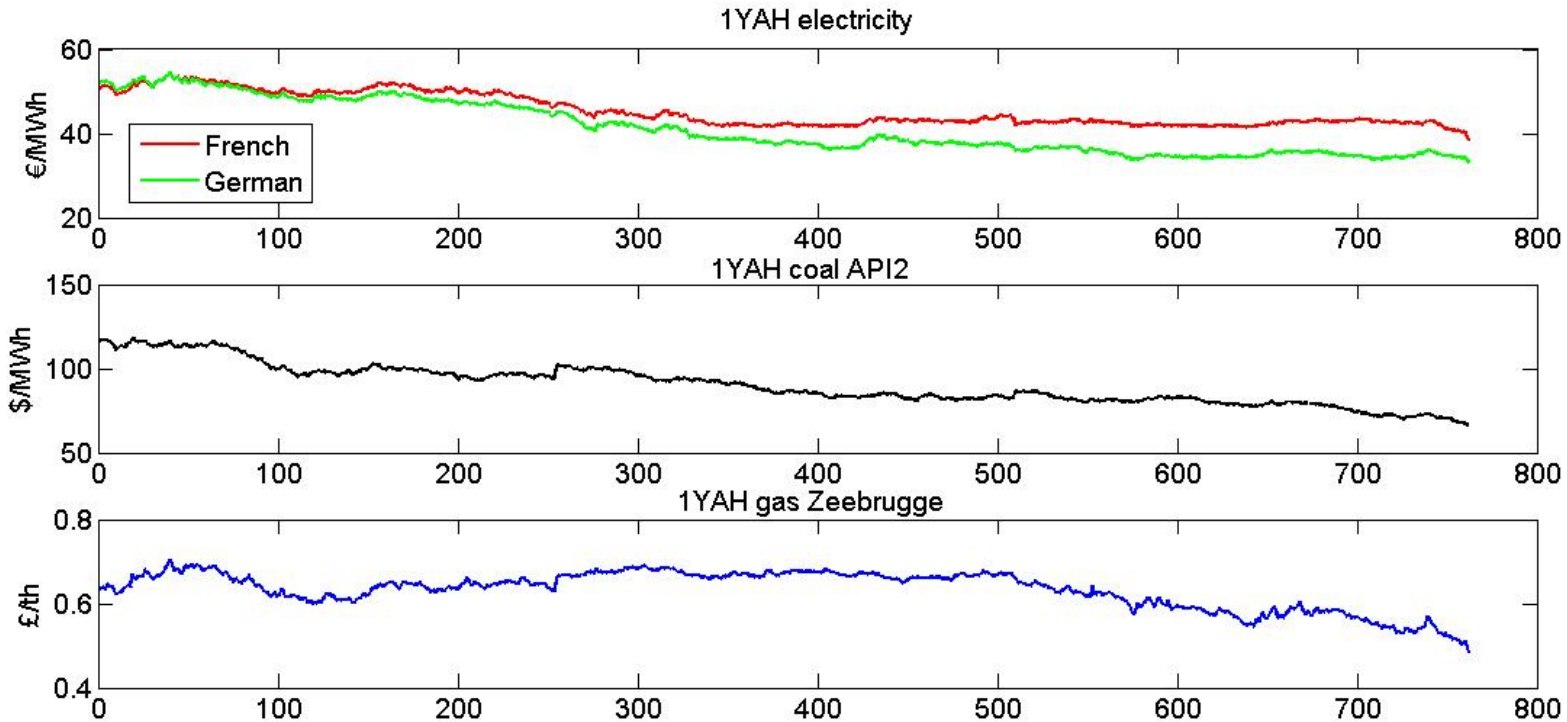



FIGURE: forward 2012-2014 (source EDF Trading)

# Peaks and link with system variables (demand, capacities...)

Power is known for its peak (positive and negative) and its strong link to available capacity and demand level.

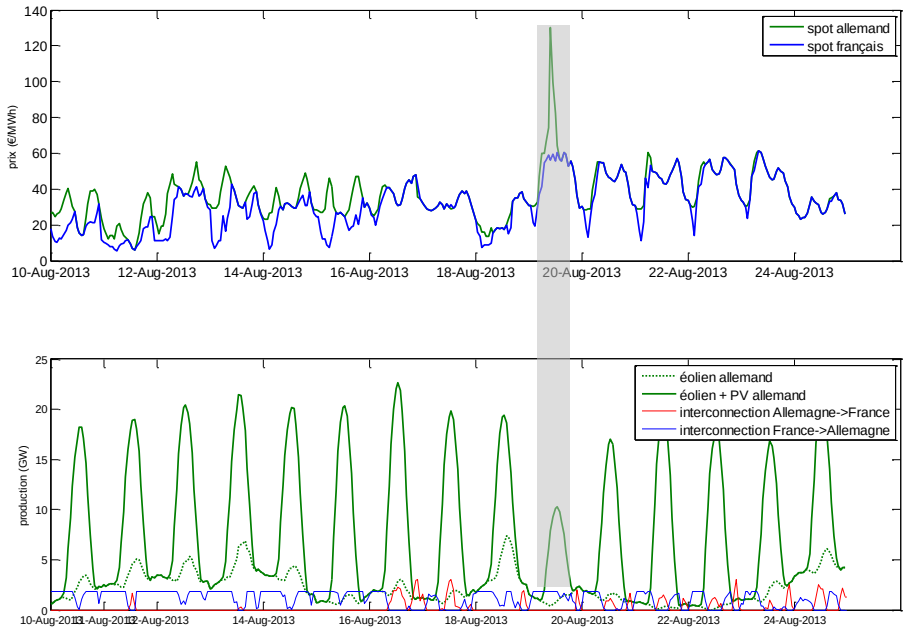



FIGURE: Sources : Epex (spot prices), ENTSOE (interconnections), Energy Data Base (German wind production), EEG (German solar production, caution this volume corresponds to only 9/10 of the total solar production)

# Plan

1 Motivations and context

2 Price models
- Different types of models
- Fund. model for LT
- HJM model for MT

3 Conclusions

# Different types of price models

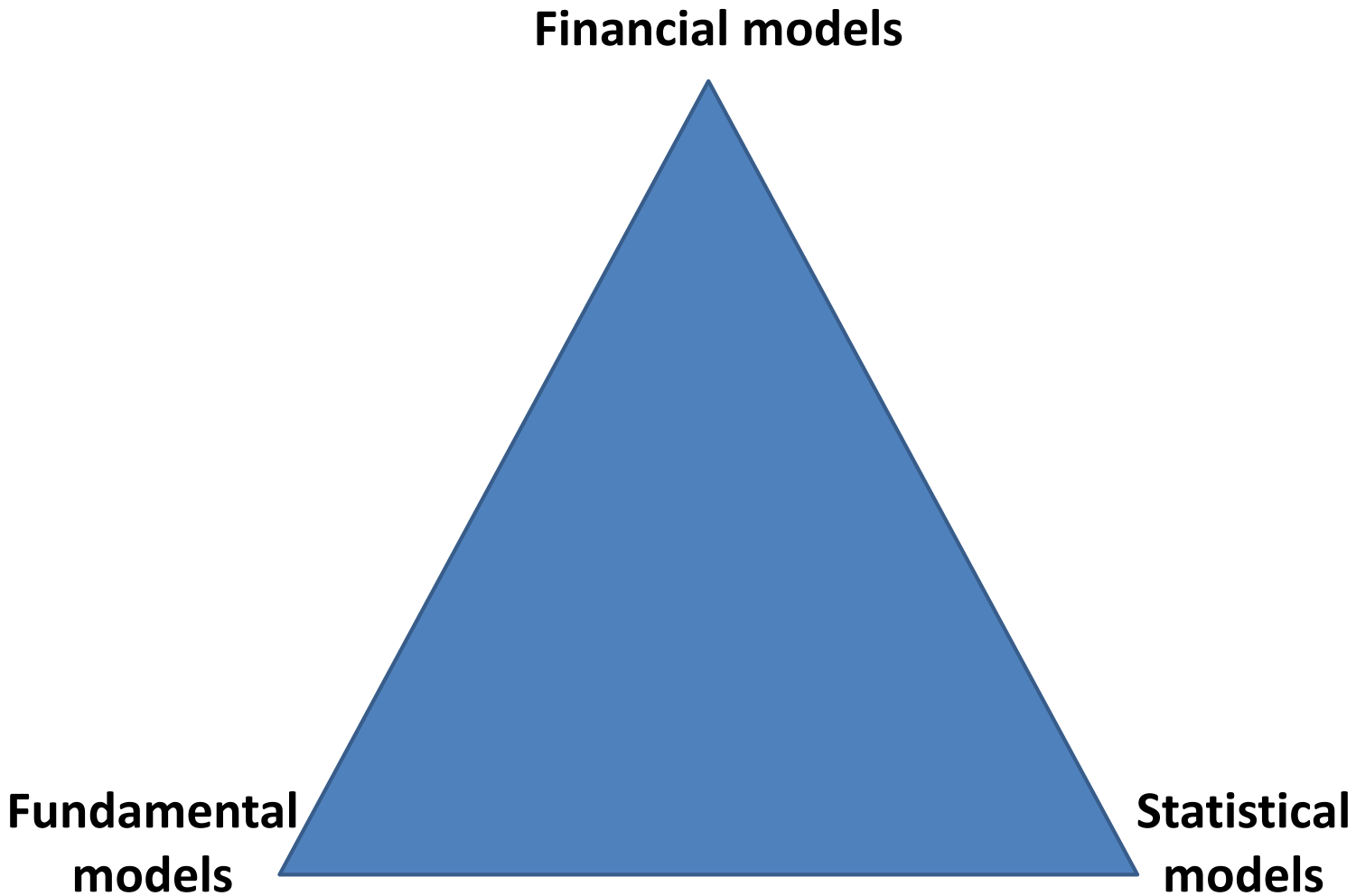
**Fundamental approach** The objective is to reproduce the physical phenomenon of price construction. The main principles rely on

- Modelling fundamental factors (temperature, wind, economical factors,...)
- offer / demand equilibrium (merit-order), marginal cost
- Modelling a spread between marginal cost and spot price

**Financial approach** The objective is to build a model that is able to give (easily and quickly) a price on derivatives and the associated hedging strategy. This strongly constrains the class of models.

**Statistical approach** The observed data are considered as a time series of values along time. The identity of the signal is forgotten. The main objective is to understand the behaviour of prices without subjective information.

# Different types of price models for different applications



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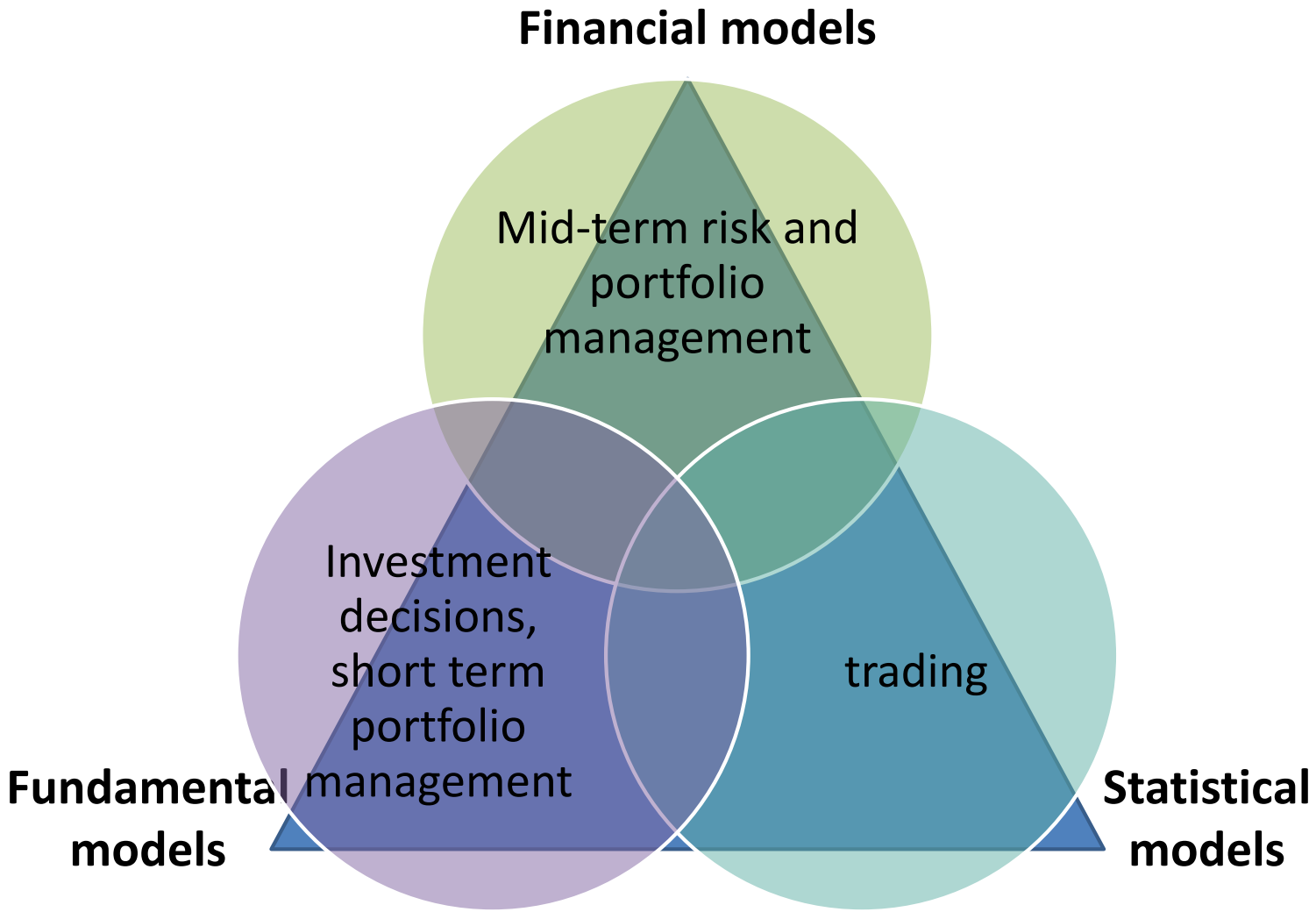


# Price models for long-term issues

For long-term issues, i.e. mainly investment decisions, the preferred price models are fundamental.

**Objective function** minimize the costs of the system w.r.t.

- production amount satisfy the consumption in each area,
- interconnections limits are respected,
- technical constraints of production assets are satisfied
- ...

This kind of models enables to represent horizon where no market reference exist.

# Price models for long-term issues

**Input data** : usually require high skill for setting the inputs in term of fleet description, forecasting of system demand, commodity prices... The amount of data may be very high as the description of the system needs to be precise enough.

**Stochastic representation** is required : the future is highly uncertain. This makes the optimization problem quite complex but also the analysis of the results.

This kind of model produces marginal cost of the system that often considered as spot prices. No forward prices simulations are available.

**Parsimonious structural models** are a credible alternative but decrease the realism of the modelled system. It may be difficult to make people take strategic decisions with them.

# Example of HJM model for mid-tem management and pricing

Several models exists, HJM (Heath, Jarrow and Morton) model is a well-known candidate (see [Kiesel (2009)] for a 2-factor version applied to electricity markets).

$$\frac{dF}{F}(t,T) = \sum_{i=0}^{N} \sigma_i(t,T)\, dW_t^i \tag{1}$$

with $\sigma$ the volatility and $W$ brownian motions

**Pros** : coherence spot/forward, explicit formula for European options and fast simulations

**Difficulties**

- Miss some key caracteristics of electricity prices, especially link between commodities and other variables is weak, peaks for spot price
- Expertise is needed on calibration

Alternatives exist : 1 factor spot model, hidden state spot model (derived forward expressions afterwards), structural models...

# Number of factors

Each product (i.e. delivery date $T$) can be driven by its own risk factor. But one can observe that forward product are not moving independently from one another.

Some empirical results, for example Koekebakker on Northpool prices (2005) show that more factors are required to represent electricity compared to other commodities.

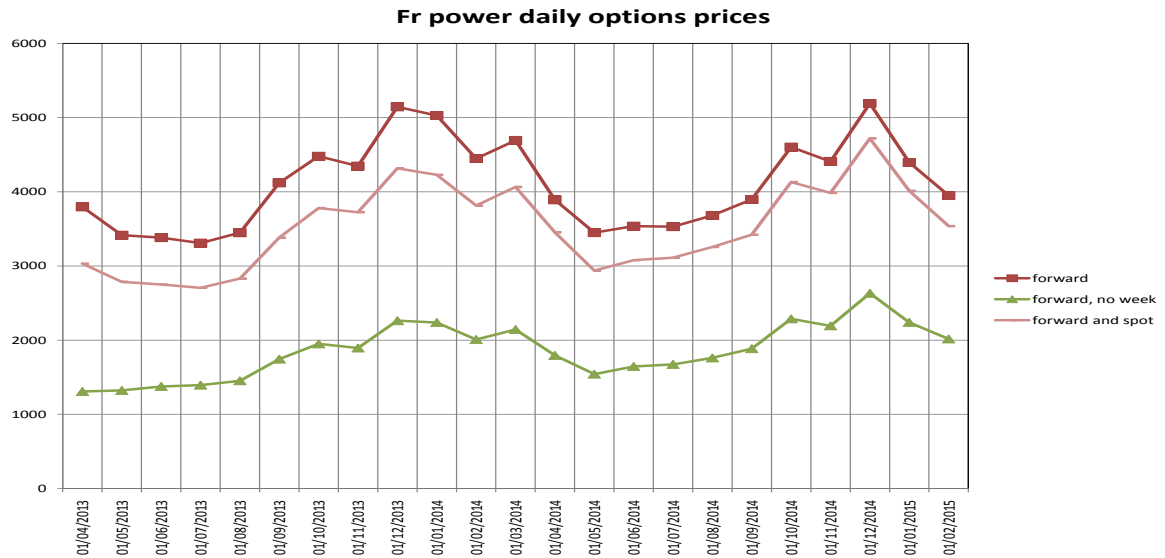
An empirical study [Deschatre (2015)] on UK prices shows on period 2011-2013 that

- **UK power prices** : 5 factors explain more than 90 % whereas 2 factors explain only 80 % of variance of prices
- **Vault coal or NBP gas prices** : 2 factors explain between 85 and 90% of prices, 3 factors explain more than 90 % of variance of prices

# Example of calibration impact

Calibration may be highly impacted by **the choice of products used.**

Example of MtM of a strip of daily and monthly European options for the French market calibrated over the period 2012-2013 with a 2-factor model.




| French Market | forward | forward, no week | forward + spot |
|---|---|---|---|
| MtM daily option | 94,136 | -14% | -50% |
| MtM monthly option | 40,872 | 0% | -8% |

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# Conclusions

Several types of models exist but many open questions are left to the practionners to make choices between them.

Model evaluation and comparison : some possible criteria

- Realism : ability of the models to reproduce the statistical properties of the spot and forward prices time series.
- Consistency : no-arbitrage property between spot and forward prices + dependencies with fuel prices or other observed variables.
- Efficiency : fast computation of forward prices and simplest options (spreads).
- Robustness : continuity of the parameters estimation w.r.t. data + continuity of the spot and forward prices w.r.t. to parameters.
- Genericity : applicable to different electricity markets.

A commun platform which enables models comparisons against several criteria would help greatly the practionners !

# References I


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