Pricing Virtual Power Plants (VPP) under a Lognormal Swap Market Model
A Trader's Model

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Outline

- E.ON Energy Trading
- VPP contracts & Asset-Backed Trading
- Valuation of VPPs
- Spread model
- Model Inputs
- Conclusion

We are at the commercial heart of E.ON

We are responsible for the commercial interests of E.ON which result from

About 60 GW of power generation capacity in Europe

Natural gas sales of >1,000 TWh

30 million customers in the EU

We optimize E.ON’s assets and actively manage price risks

E.ON Energy Trading is responsible for commodity risk management and the optimization of E.ON‘s assets 3 years prior to delivery.

By actively trading on the futures markets, we minimize the price risks for E.ON’s power production.



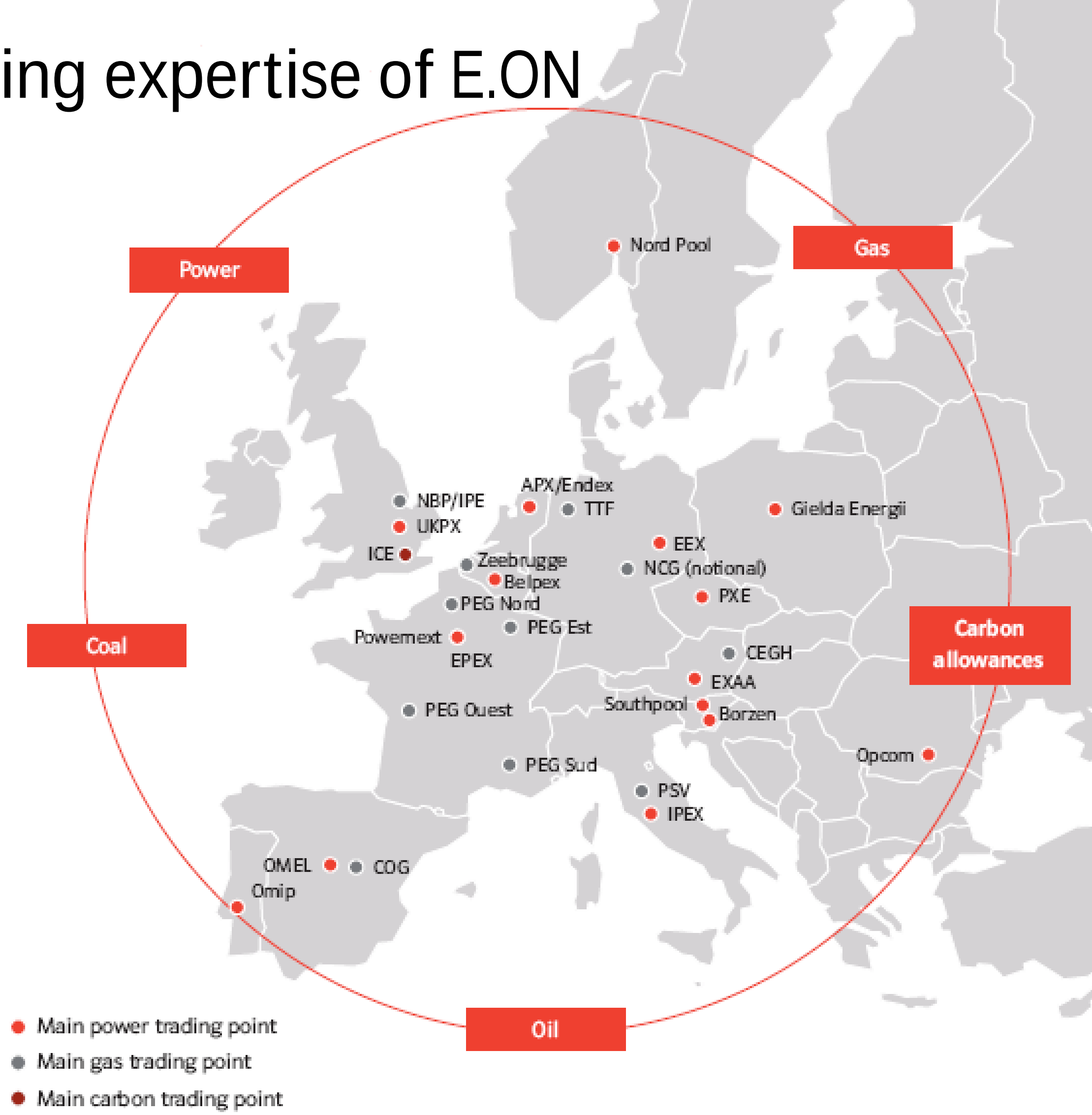

We unite the entire trading expertise of E.ON

We trade in all major European markets.

We are active at all major exchanges.

We are active in 40 countries.

All E.ON's European trading expertise is united in Düsseldorf.



We have a large stake in the international energy markets*

Power: 1,240 TWh
Gas: 1,498 TWh
CO_2 allowances: 501 million t
Oil: 69 million t
Coal: 223 million t
Adjusted EBIT: 949 million €

(*All numbers cited are for 2009)

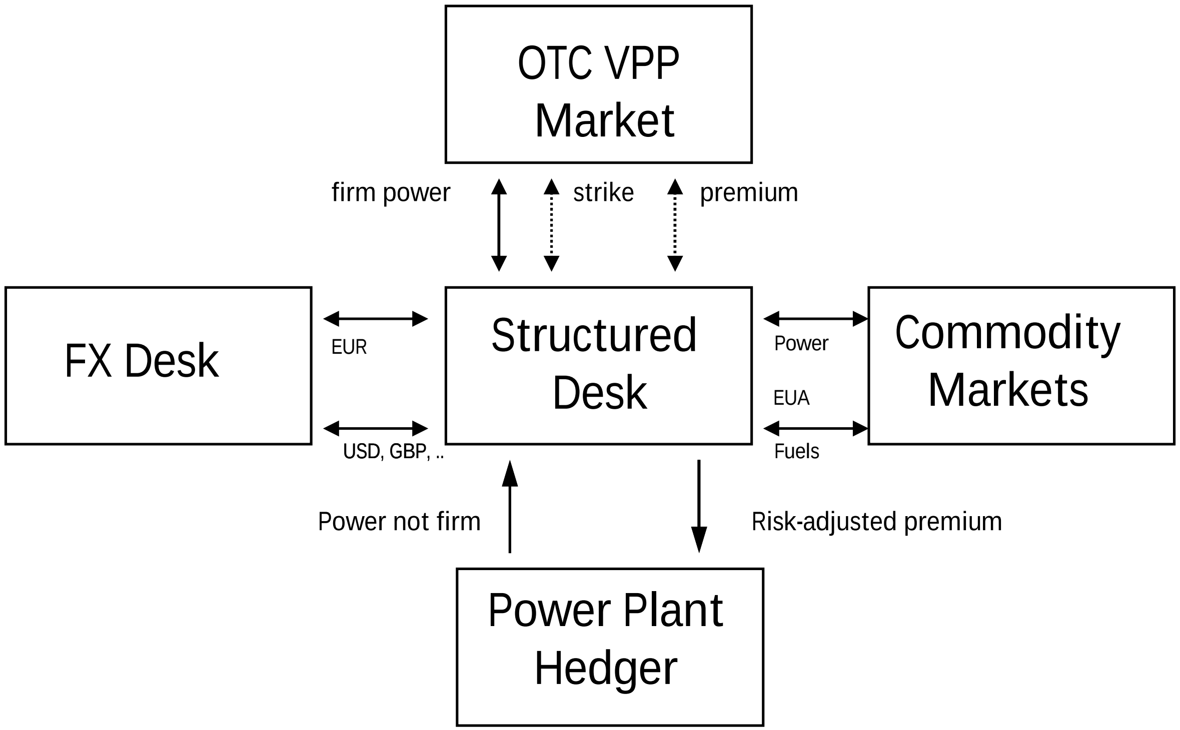
VPPs & Asset-Backed Trading

Asset-Backed Trading is a style of commodity trading…

- Seeks to exploit market volatility to monetise operational asset flexibility
- Views physical assets as portfolios of traded instruments
- Example: a merchant power plant considered as a strip of spread options
- Use of pricing and modelling techniques adapted from financial markets

Asset-Backed Trading at the Structured Desk comprises...

- •Market making for VPP contracts
- •Volatility trading and forward spread optimisation
- •Management and mitigation of physical and financial risks



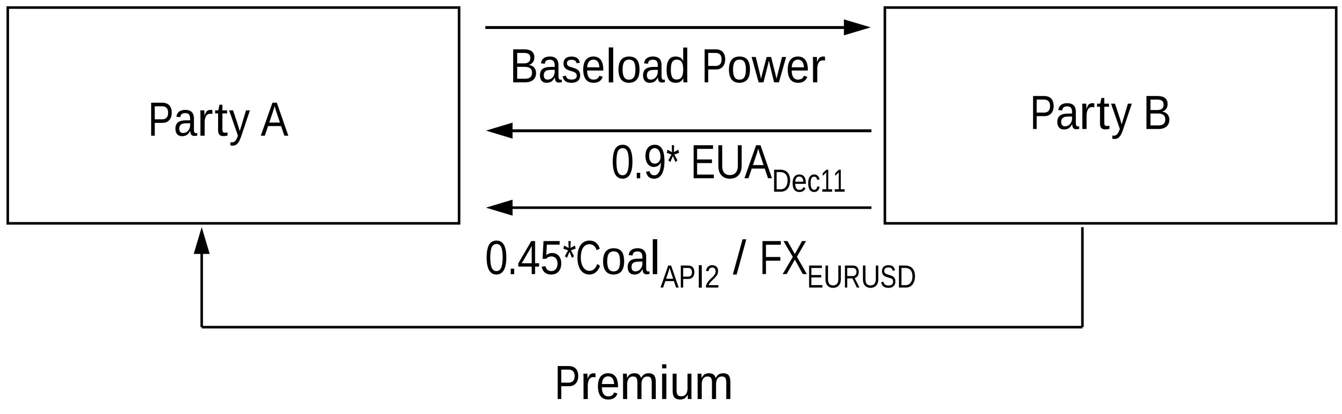
Main risks transferred from plant hedger:

- •Market price risk (revenues must cover debt servicing & IRR)
- •Technical/asset trip risk
- •FX-exposure

VPPs are the workhorses of asset-backed power trading...

- Bespoke synthetic power asset contracts, increasing standardisation
- Retain some physical plant characteristics (e.g. start cost, ramp rates)
- Modelled as strip of spread options
- Premium reflects operational constraints and residual risks

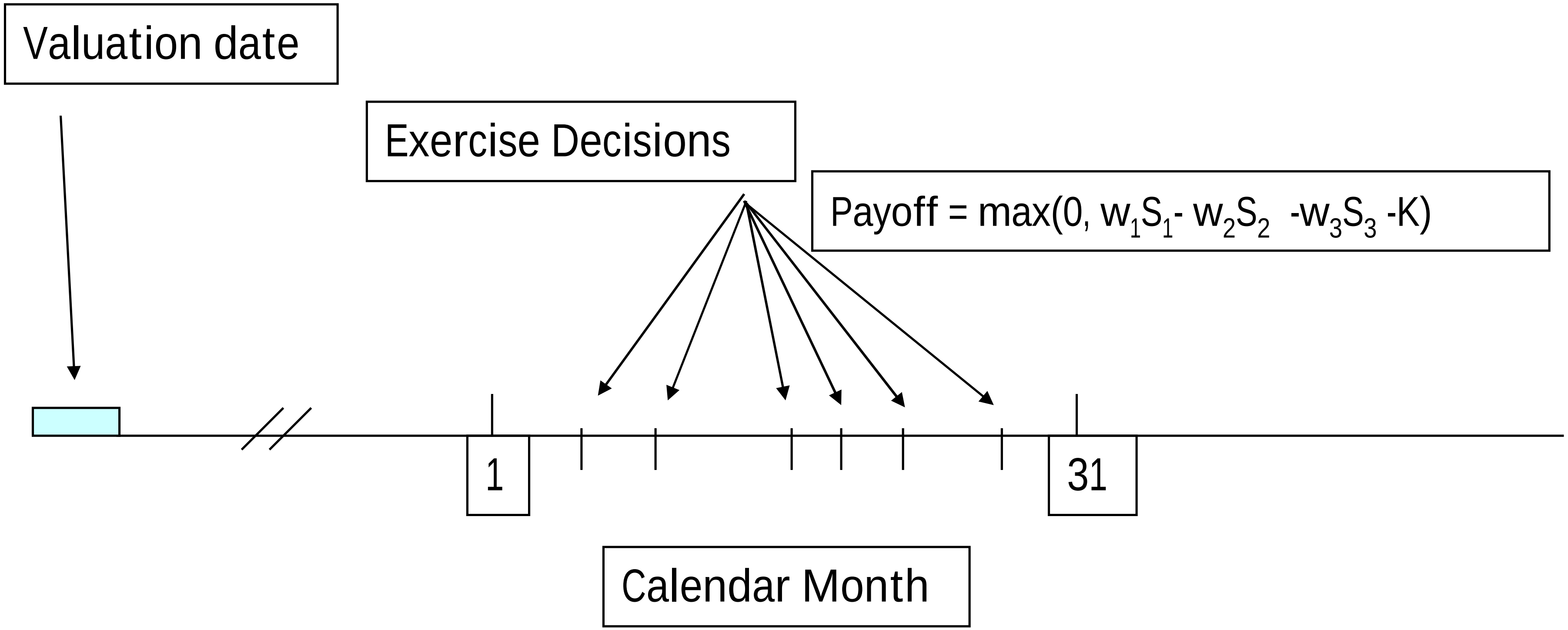
Example VPP transaction: A sells to B a virtual coal-fired plant with daily baseload nomination rights



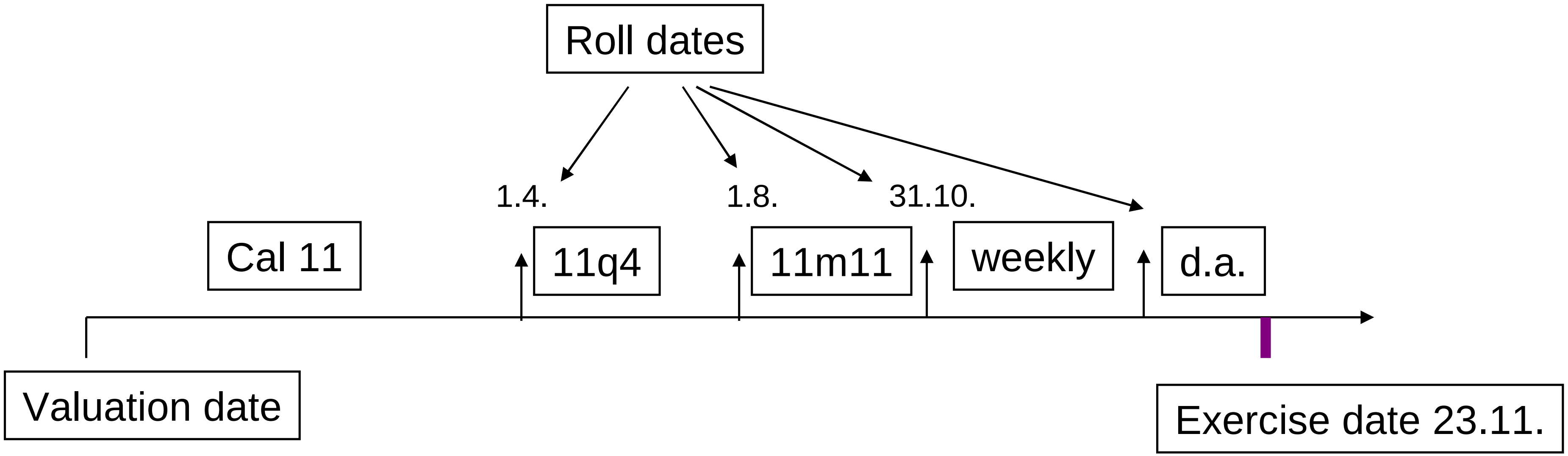
VPP Valuation

Strip of Daily Options

- Consider a VPP contract with daily exercise rights
- In absence of physical constraints value as a strip of daily spread options



Valuation based on Tradables



Estimate of the value of each option in the strip based on the tradables in the current market structure i.e. Cal, Q, seasonal etc.

Spread Option Model

Spread Option Model

- Model the underlying swap rates as martingales under the risk neutral measure
- One driving factor for each underlyer and traded contract in the current market structure i.e. Cal, Q etc.
- Time dependent but deterministic volatility function

$$\frac{dF(t,T_i)}{F(t,T_i)} = \sigma(t,T_i)dW_{T_i}(t) \qquad i=1,2,\ldots,N$$

$$\Leftrightarrow \qquad F(t,T) = F(0,T)\exp\left(\int_0^t \sigma(s,T)dW(s) - 0.5\int_0^t \left|\sigma(s,T)\right|^2 ds\right)$$

Assume further a correlation structure of the Wiener increments

$$E\left\lfloor dW_{T_i}(t)dW_{T_i}(t)\right\rfloor = \rho_{ij}dt$$

Spread Option Model

•The value of the VPP contract per MW of power capacity is then given by

$$VPP = \sum_{i,strip} e^{-r*(T_i - t)} E_t^Q \left[(w_1 F_{i,1} - w_2 F_{i,2} - w_3 F_{i,3} - K)^+ \right]$$

•The value of each spread option in the strip is given by the discounted risk-neutral expectation of the option‘s payoff.

•This expression is sufficiently easy to evaluate, e.g. by Monte Carlo simulation.

•Greeks are easily estimated as sensitivities of the VPP price w.r.t. to the underlying value drivers.

•Some similarity to the approach followed by LIBOR models in the interest rate space in the sense that tradables are the building blocks

Inputs: Volatility & Correlation

Forward Volatility Calibration

We have the relationship for the instantaneous volatility with the implied volatility given by

$$\sigma^{imp}_{F(0,T_i)} = \sqrt{\frac{1}{T_i}\int_0^{T_i} \sigma^2(u,T_i)\,du}$$

Consistent with market observation write volatility in a parsimonious parametric form

$$\sigma(t,T_i) = \sigma_1 + \sigma_2 . e^{-\kappa(T_i - t)}$$

σ_2 Short-term vol level
σ_1 Long-term vol level
κ decay factor

- Forward volatility depends on time to expiration *(T-t)* rather than absolute time *t*
- Exponentially decaying volatility function (for each underlying leg)
- Can account for length of underlying swap delivery (Kiesel 2007, Benth 2008)

Forward Volatility Calibration

Given the parametric form for the instantaneous volatility we find for the model implied volatility:

$$\sigma^{imp}_{F(0,T_i)} = \sqrt{\sigma_1^2 + \frac{2\sigma_1\sigma_2(1-e^{\kappa T})}{-\kappa T} + \frac{\sigma_2^2(1-e^{2\kappa T})}{-2\kappa T}}$$

Robust estimation of the parameters of the local volatility function by least squares procedure, i.e. solve

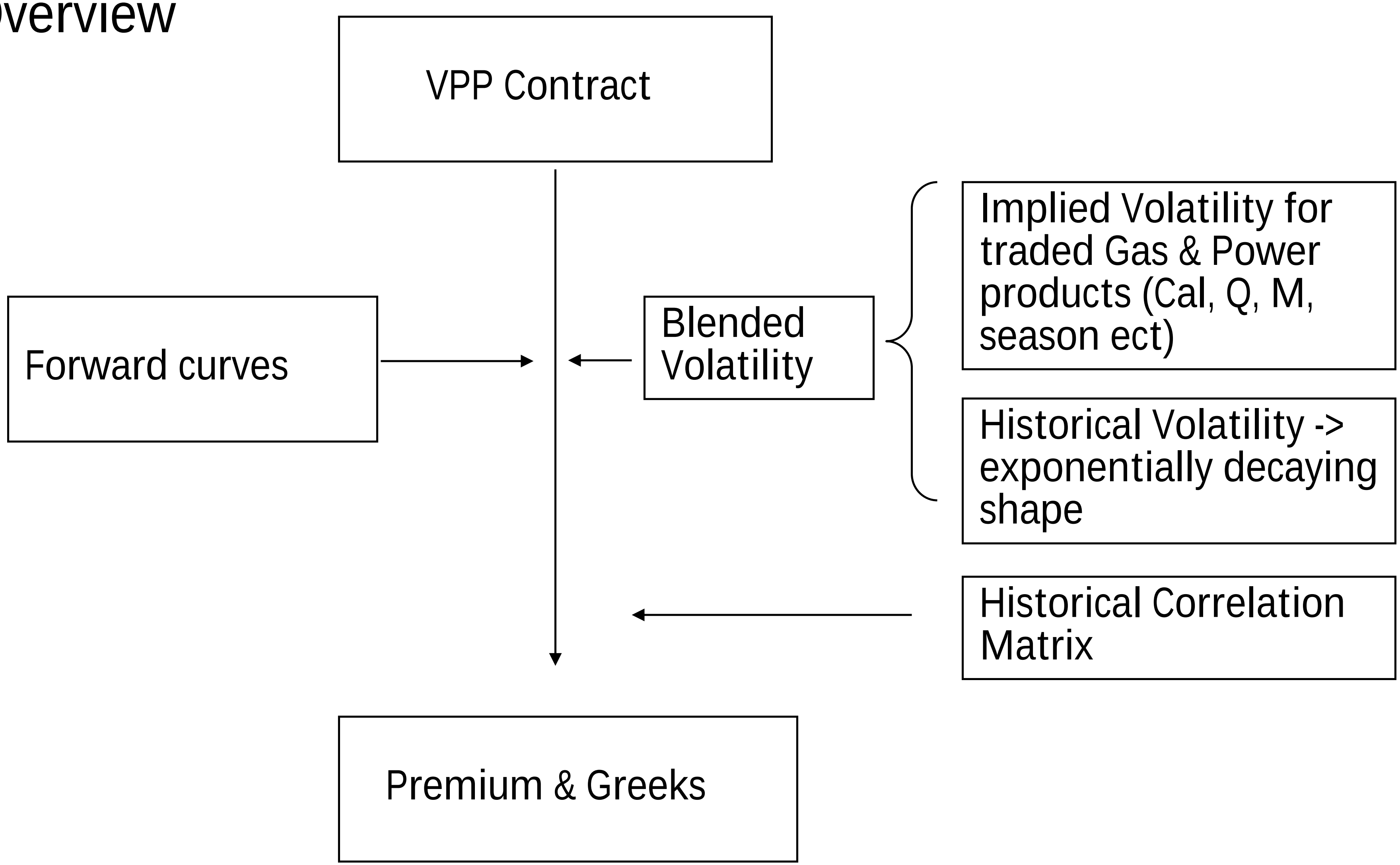
$$\min_{\{\sigma_1,\sigma_2,\kappa\}} \sum_{mktquotes} \left[\sigma^{imp}_{F(0,T_i)} - \sigma^{model}_{F(0,T_i)}\right]^2$$

Correlation Input

- Difficult to imply from the market -> estimation from historical data (requires long time series)
- Estimate fuel-to-power, fuel-to-co_2, co_2-to-power and FX correlations for Cals, Qs, months, weeks
- The crucial quantity for valuing and hedging European options is the terminal correlation

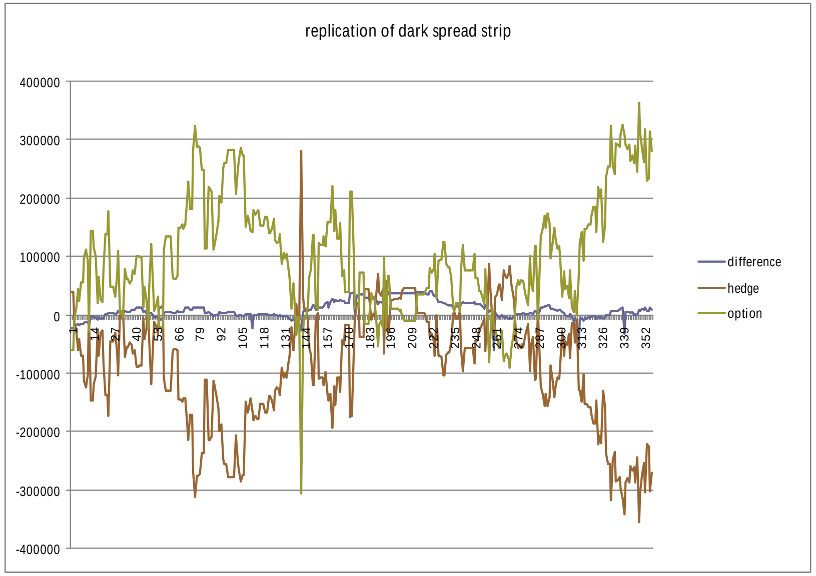
$$\rho(t,T) = \rho_{\ln S_T, \ln G_T} = \frac{E_t[\ln S_T \ln G_T] - E_t[\ln S_T] E[\ln G_T]}{\sqrt{\mathrm{var}[\ln S_T]}\sqrt{\mathrm{var}[\ln G_T]}}$$

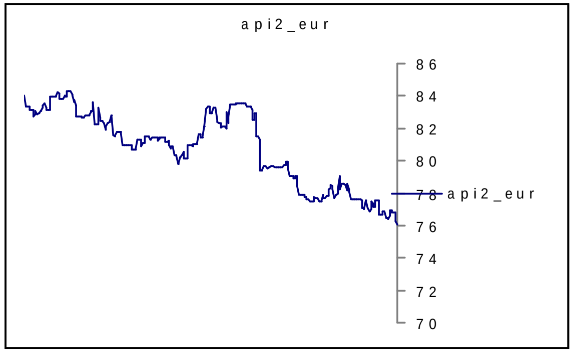
Overview

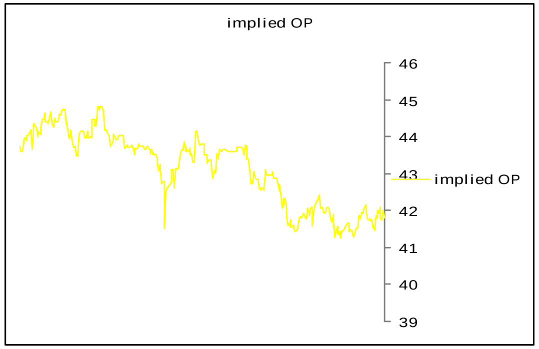

VPP Contract
Forward curves
Blended Volatility
Implied Volatility for traded Gas & Power products (Cal, Q, M, season ect)
Historical Volatility -> exponentially decaying shape
Historical Correlation Matrix
Premium & Greeks

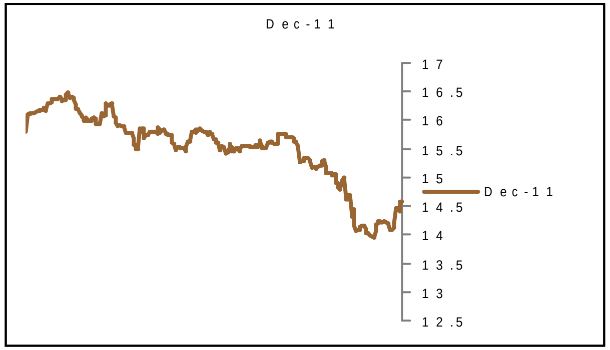
Model works very well…

•Low tracking error - almost perfect replication of a OP dark spread VPP









...and meet‘s the trader‘s model desiderata:

- Link valuation to practical hedging strategy
- Fast calibration to market implied volatilities
- Fast premium and Greeks
- Ablility to correctly price vanilla products traded in the market
- Transparency of model allows intuitive interpretation of the deal value‘s sensitivity w.r.t. drivers/inputs (correlations, volatilities)
- Philosophy: As complex as necessary as simple as possible

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