Amsterdam, 23 February 2017
Intelligent Hedging and Portfolio Optimization Summit for the Energy Market

Assessing dynamic hedging strategies

www.kyos.com, +31 (0)23 5510221
Cyriel de Jong, dejong@kyos.com

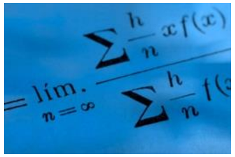
KYOS Analytical Platform

Gas Markets

- KyStore - Gas storage valuation / hedging
- KySwing - Swing (option) contract valuation / hedging

Power Markets

- KyPlant - Power plant valuation / hedging
- KyCurve - Hourly price forward curves (incl. intra-day)
- KyPowerFundamentals - Fundamental power market modelling



Price and Risk Management

- PRM / ETRM - Portfolio & Risk Management System
- KyRisk - Earnings-At-Risk reporting and analysis
- KyVaR - Value-at-Risk reporting and analysis
- KySim - Monte Carlo price simulation

Why dynamic hedging?

- Reduce price exposures
- Make more money, for example because:
  - You are long flexibility (gamma)
  - You can be more active in short-term markets

But: weigh benefits against costs of trading and other risks (liquidity, credit)

How to trade successfully, consistently?

- There should be a clearly defined and sensible hedge target
- There should be a clear process which leads to hedging decisions
- Traders should know their benchmark and be assessed against this benchmark
- The performance of the whole strategy should be monitored quite frequently

Elements of the “benchmark” hedging strategy

- Which assets / contracts?
- Over what horizon?
- With what trading products?
- With what frequency of rehedging?
- Against which prices?
- With what assumptions about trading costs?
- Using what calculation of exposure?
  - Intrinsic versus Delta
  - Volume-neutral versus Value-neutral or Risk-minimal?

Delta exposures and delta hedges

Delta (exposure): change in contract or asset value as a result of a small change in the underlying price:

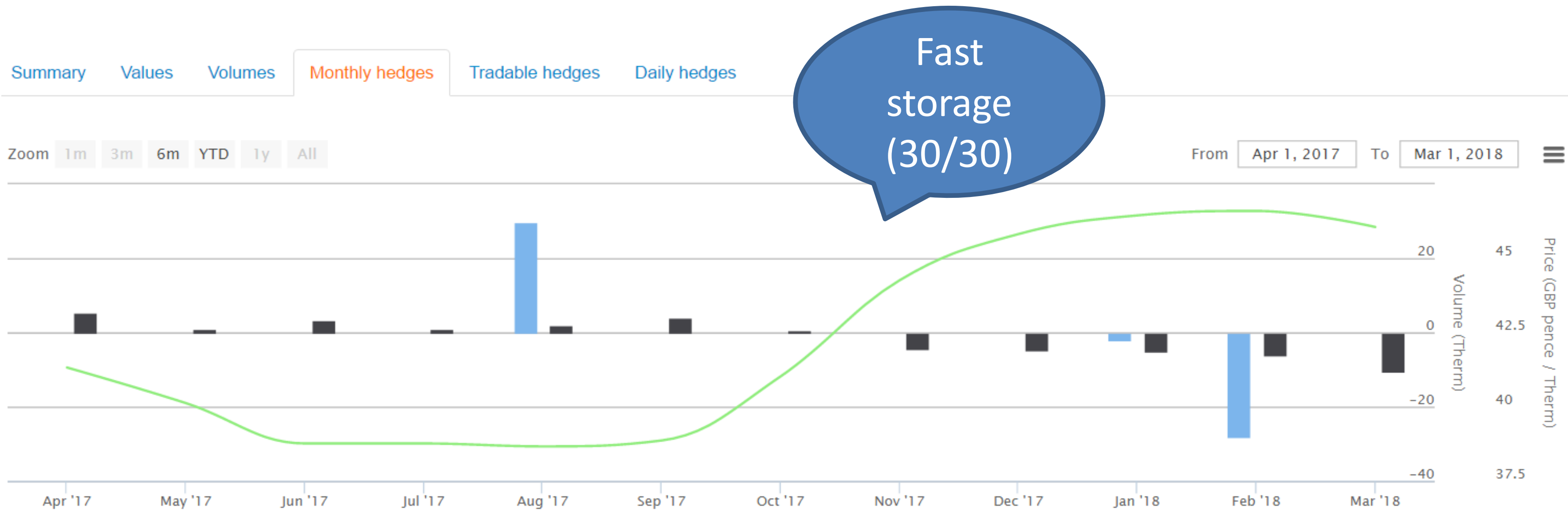
E.g. taking a call option C: $\delta = \Delta C / \Delta S$

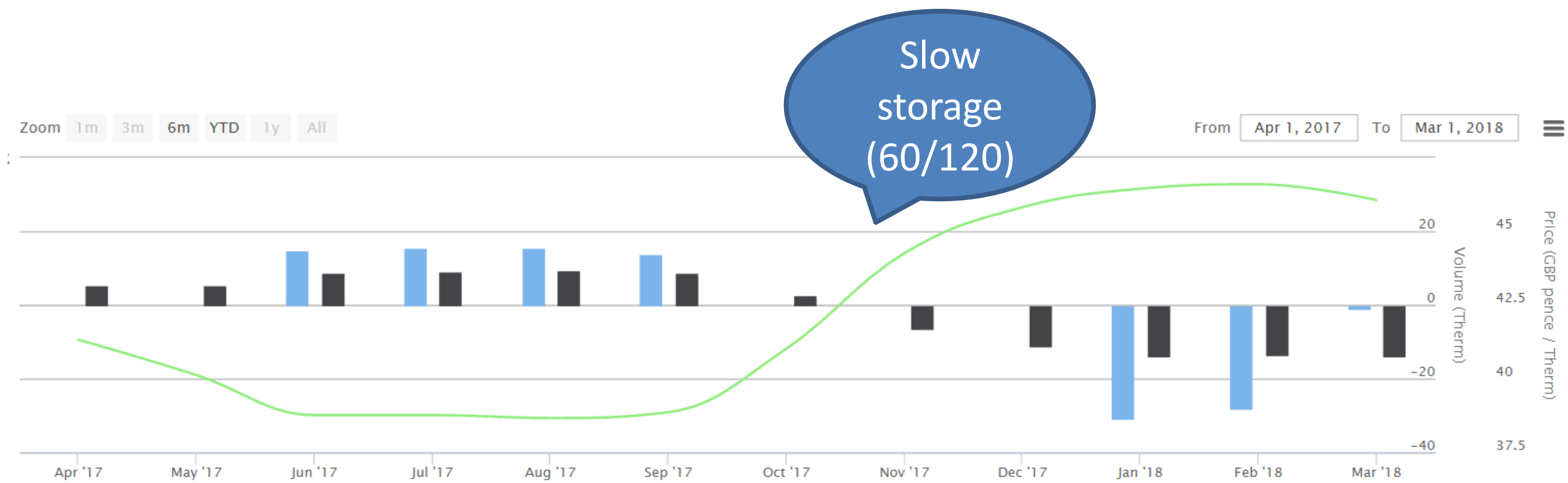
Note:

- Delta hedges can be calculated for a range of exposures / commodities
- Delta hedges can be calculated for a range of products and granularities
- Delta hedges can be compared to intrinsic hedges

KYOS

Delta/Intrinsic hedges for a gas storage





How to calculate delta sensitivities? (1)

Example:

- Value of the storage is 10 mln €
- We need delta for Jan-17, forward price is 25 €/MWh

Approach 1 = shock based / finite difference:

- Increase Jan-17 price to 25.01
- Recalculate storage value: 10.0161 mln €
- Delta = 0.0161 mln / 0.01 = 1.61 mln MWh
- Note: recalculation may use parts of the main calculation, but calculation time is long if this is applied to each month

Approach 2 = Basket of spreads:

- Define storage as set of spread options and calculate delta per option
- Note: not very accurate, due to overlapping nature of storage

How to calculate delta sensitivities? (2)

Approach 3 = volume approximation:

- Suppose that the average withdrawal in Jan-17 is 1.5 mln MWh
- Then a 0.01 €/MWh increase in all prices, and assuming unchanged strategy, increases the value by 15,000 €
- Hence, delta = 1.5 mln MWh

Approach 4 = value approximation (very accurate):

- Suppose that the average withdrawal in Jan-17 is 1.5 mln MWh
- On average, the value of the withdrawals is 40.5 mln € (average withdrawal price is 27 €/MWh)
- Then the delta is 40.5 / 25 = 1.62 mln MWh
- Note: this can be implemented easily and is calculated quickly

Three main approaches to hedging

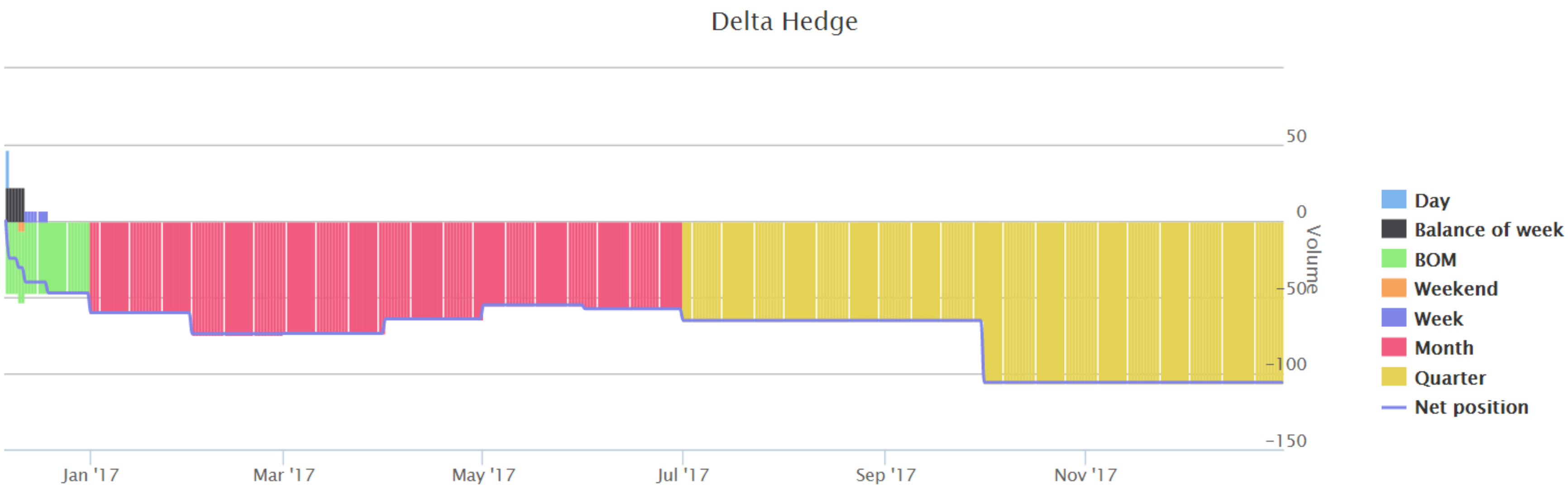
1. Intrinsic hedging, possibly rolling (forward curve)
2. Hedging the expected future volumes (Monte Carlo)
3. Hedging the expected future value (Monte Carlo)

Note:

- 3 is (almost) equal to the true delta hedge
- 2 may be quite close to 3
- 1 can be very suboptimal (though you may be lucky)

Translating delta exposures to trades

- Model may calculate daily or monthly delta exposures
- Should be netted with existing position and other exposures
- Remainder should be most effectively traded in the market:
  - Minimize transaction cost
  - Minimize open position / risk, either in terms of volume, value or risk (Earnings-at-Risk)



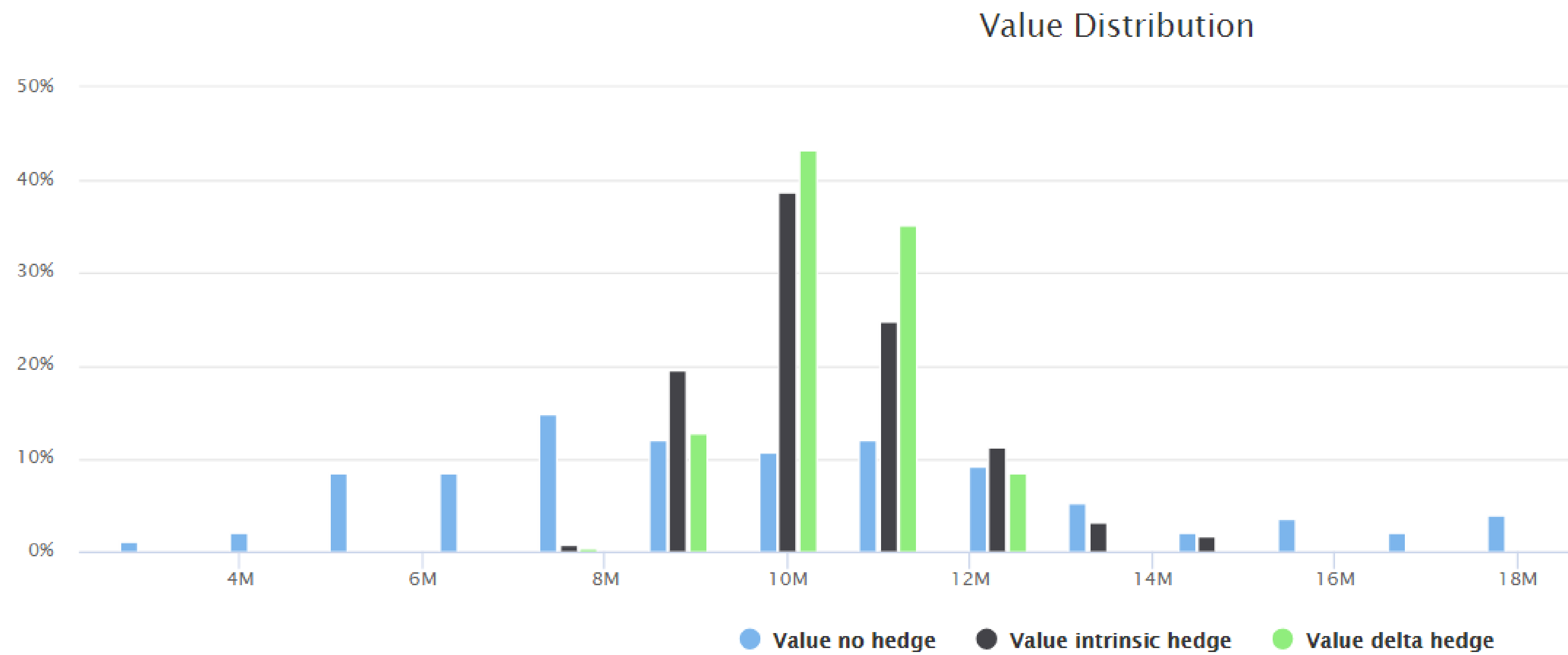
KYOS

Example of hedge impact on Earnings

View results for profile DE - Coal 40pc

KyPlant profile 9	Power plant DE - Coal 40pc	Start date 2017-01-01
Job ID 53505	Job created at 2017-02-22 23:20:03	Trading date 2017-02-22

Value | P&L | Hedge | Operation Statistics | Hourly Dispatch | Comparison



Calculating dynamic hedges within simulations

- For the current day t, the above approach(es) can be used to calculate the hedges
- Likewise, based on historical market prices, the hedges can be calculated at past periods and used to analyze 'model-based' past hedge performance
- However, to analyze a dynamic hedging strategy in the future, we need:
  - To simulate spot and forward prices $F(t,T,i)$
  - For each future date t and simulation i, estimate the optimal hedge of a forward with delivery T

KYOS

Intuition of dynamic hedges within simulations

- Let’s consider a CCGT power plant and it’s exposure to 2018 spark spreads. Max capacity is 100 MW.
- Today (Feb-17) suppose:
  - Peak spark spread for 2018 is 5 €/MWh
  - Using Monte Carlo simulations the delta hedge is 40 MW
- How will this hedge evolve over time? Consider 1 July 2017:
  - Sim 1: 2018 spark spread = 10 €/MWh → hedge = 60 MW
  - Sim 2: 2018 spark spread = 0 €/MWh → hedge = 20 MW
- The optimal rehedge volumes can be calculated with regression analysis: “path dependent delta hedges”

KYOS

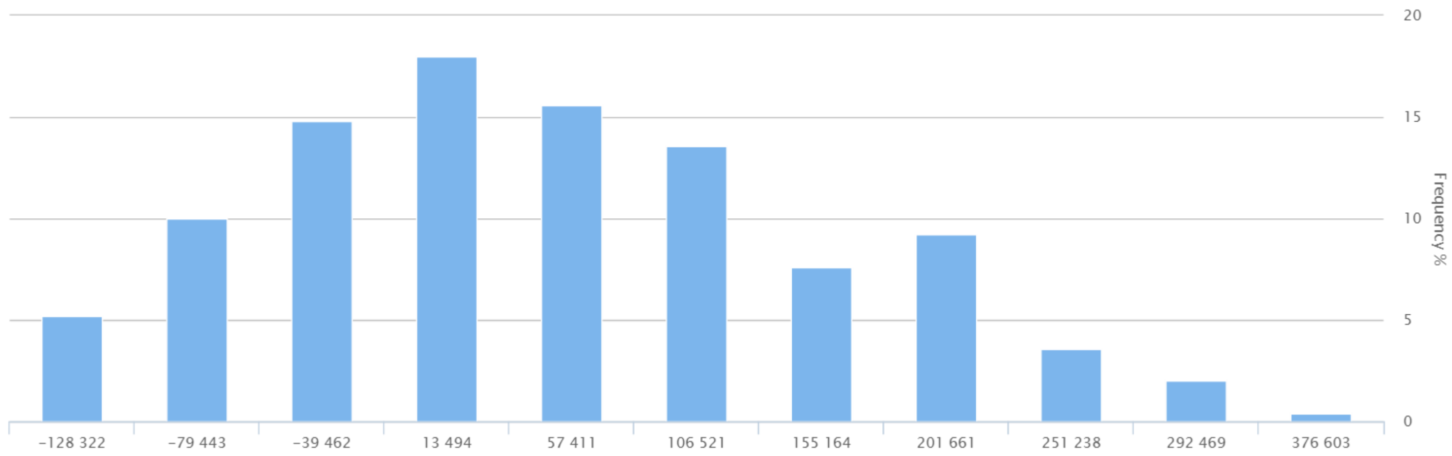
Earnings-at-Risk / Cashflow-at-Risk

What is EaR/CfaR?

What is the distribution of future earnings or cashflows of my portfolio?

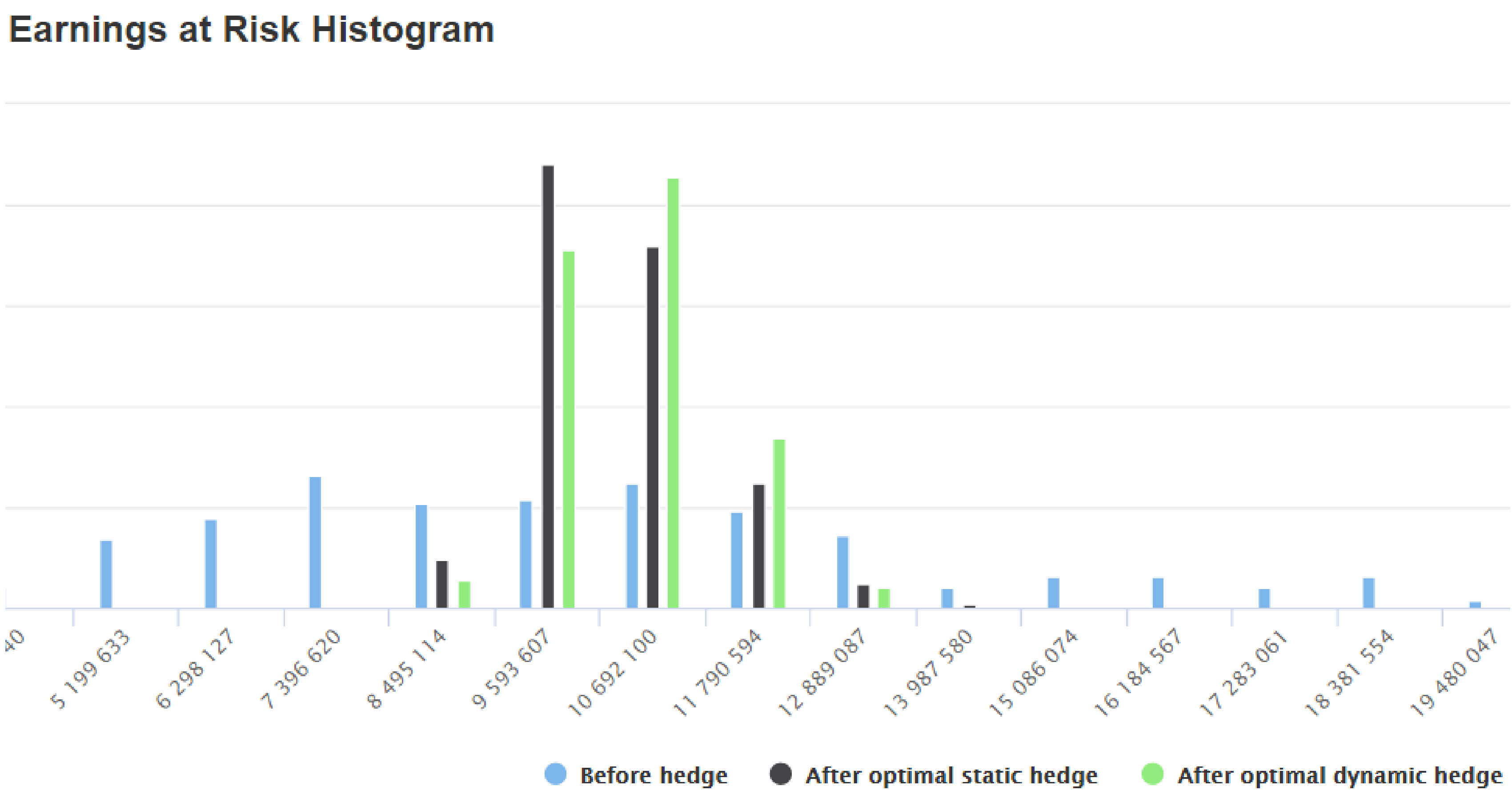
Difference VaR and EaR/CfaR

- VaR: worst-case drop in market value over a short horizon
- EaR: worst case realization of total earnings over a long horizon



KYOS

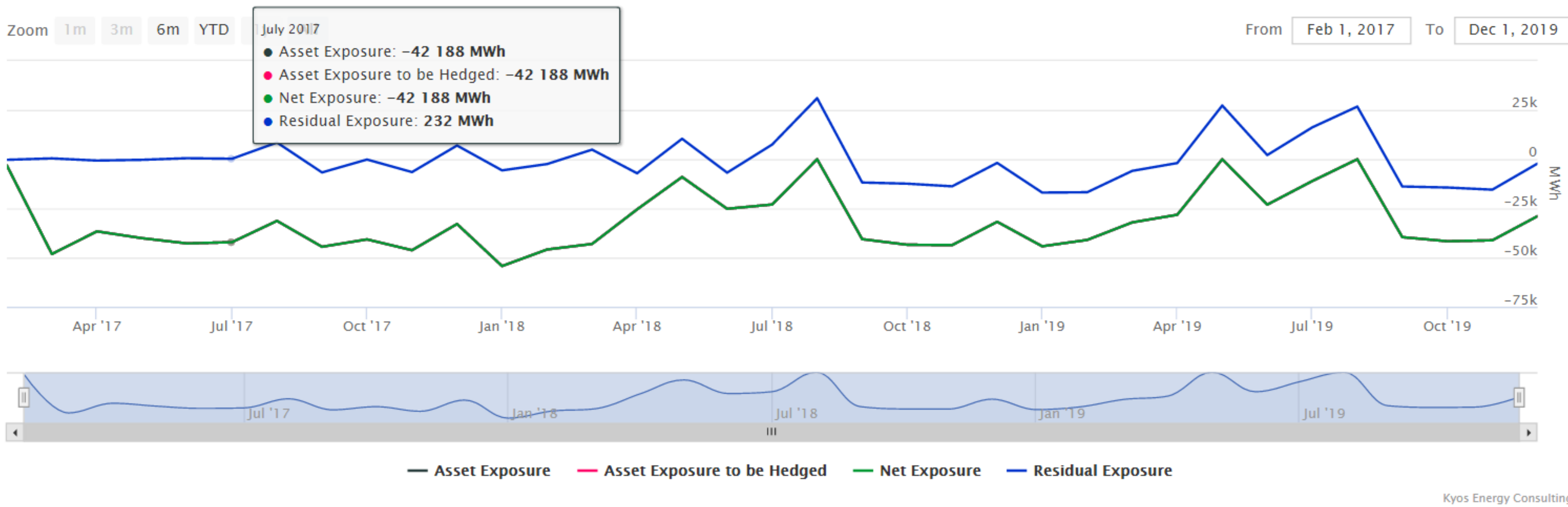
Example: impact of dynamic versus static hedge



KYOS

Optimal trades resulting from delta hedges

Commodity Exposure under Static Hedge Strategy



Show/hide hedge strategy table

Optimal Trades

Date	Product	Delivery Type	Lots	Volume	Unit	Mid Price	Trade Prices	Currency	Bid-Ask Costs	Trading Costs	Currency
2017-02-22	2017-02-23	Peakload	21	1 260	MWh	35.65	35.68	EUR/MWh	31.50	0	EUR
	BOW	Baseload	5	2 400	MWh	25.91	25.94	EUR/MWh	60	0	EUR
	BOW	Peakload	-15	-1 800	MWh	38.58	38.55	EUR/MWh	45	0	EUR
	BOM	Baseload	-5	-3 600	MWh	28.79	28.77	EUR/MWh	90	0	EUR
	BOM	Peakload	-5	-1 200	MWh	39.69	39.67	EUR/MWh	30	0	EUR
	Mar 2017	Baseload	-9	-33 435	MWh	36.69	36.64	EUR/MWh	1 672	0	EUR
	Mar 2017	Peakload	-11	-15 180	MWh	42.87	42.82	EUR/MWh	759	0	EUR

Case study: gas storage

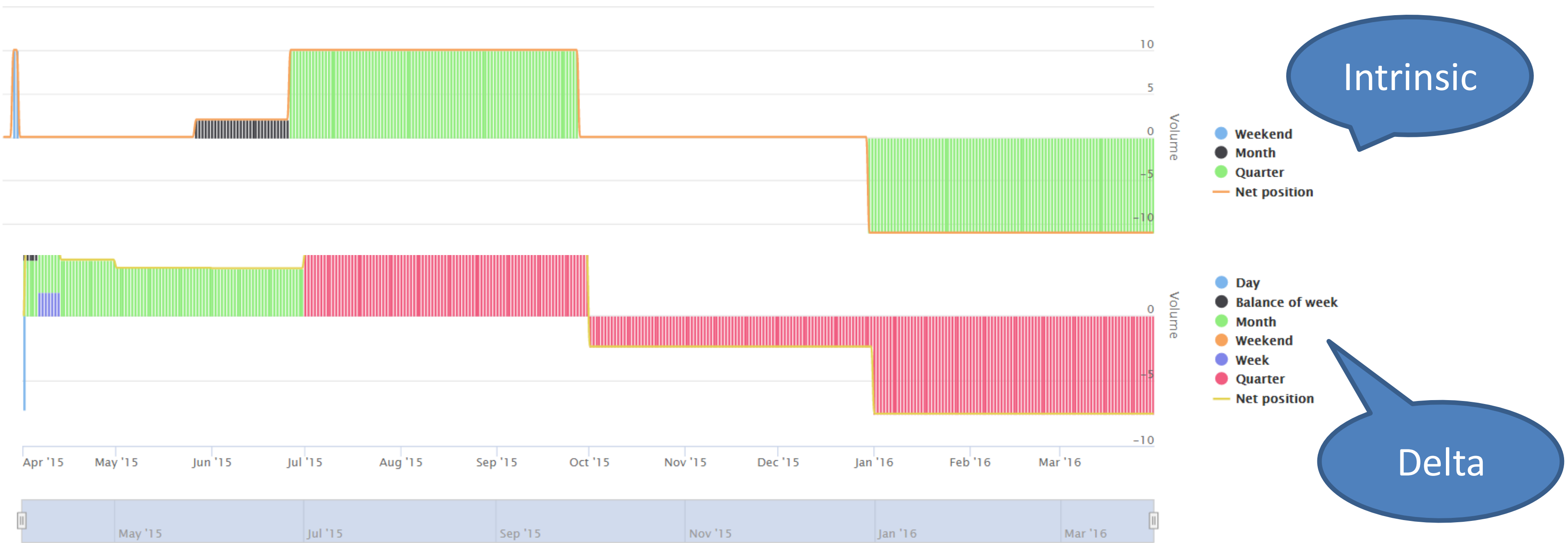
- Virtual storage in the TTF market
- Working volume of 1000 MWh
- Injection rate = 10 MWh/day, withdrawal rate = 20 MWh/day
- Injection cost = 0.5 €/MWh, withdrawal cost = 0.2 €/MWh

We consider storage year 15/16 and 16/17

Relevant questions:

- What is the (fair) value of this storage bundle?
- What trading strategy should be employed to realize this value?

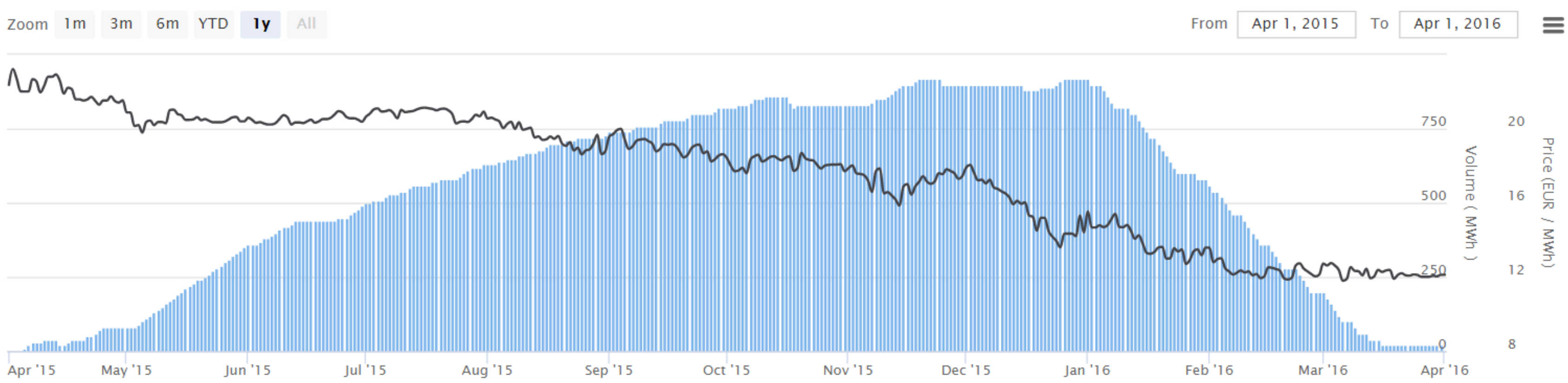
SY 15/16 – all products



Product Name	Begin Date	End Date	Bid Price	Mid Price	Ask Price	Intrinsic Hedge	Delta Hedge
2015-04-01	2015-04-01	2015-04-01	22.36	22.37	22.38	0	-7.19
BOW	2015-04-01	2015-04-05	21.67	21.68	21.69	0	14.85
Apr 2015	2015-04-01	2015-04-30	21.54	21.57	21.59	0	126.53
Apr 2015	2015-04-01	2015-04-30	21.56	21.57	21.58	0	0
Q2 2015	2015-04-01	2015-06-30	21.51	21.53	21.56	0	0
Weekend - 04 Apr	2015-04-04	2015-04-05	21.41	21.42	21.43	20	-0.09
Week - 06 Apr	2015-04-06	2015-04-12	21.51	21.52	21.53	0	12.27
May 2015	2015-05-01	2015-05-31	21.54	21.57	21.59	0	111.66
Jun 2015	2015-06-01	2015-06-30	21.44	21.47	21.49	60	106.67
Q3 2015	2015-07-01	2015-09-30	21.31	21.33	21.36	920	441.07
Q4 2015	2015-10-01	2015-12-31	22.41	22.44	22.46	0	-221.74
Q1 2016	2016-01-01	2016-03-31	22.95	22.98	23.00	-1 000	-686.18

SY 15/16

Summary | Values | Decision support | Volumes | Monthly hedges | Tradable hedges | Daily hedges | Backtest Values | Backtest Spot Decisions



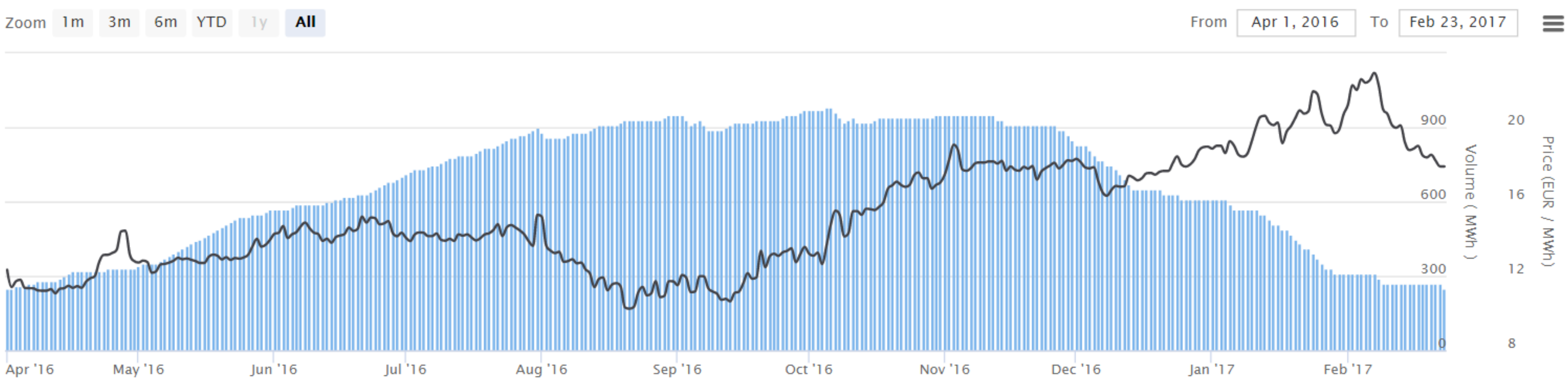
Summary | Values | Decision support | Volumes | Monthly hedges | Tradable hedges | Daily hedges | Backtest Values | Backtest Spot Decisions

Backtest Values

Strategy	Projected value (EUR)	Realized value (EUR)
Intrinsic daily	1 169	
Intrinsic monthly	1 069	
Intrinsic tradable	885.37	
Rolling intrinsic	2 228	1 436
Spot	2 525	-6 149
Spot with static intrinsic hedge		2 535
Spot with static delta hedge		1 178
Spot with dynamic intrinsic hedge		2 182
Spot with dynamic delta hedge		2 509

SY 16/17

Summary | Values | Decision support | Volumes | Monthly hedges | Tradable hedges | Daily hedges | Backtest Values | Backtest Spot Decisions



Summary | Values | Decision support | Volumes | Monthly hedges | Tradable hedges | Daily hedges | Backtest Values | Backtest Spot Decisions

Backtest Values

Strategy	Projected value (EUR)	Realized value (EUR)
Intrinsic daily	1 026	
Intrinsic monthly	959.50	
Intrinsic tradable	347.19	
Rolling intrinsic	1 244	1 316
Spot	1 513	4 272
Spot with static intrinsic hedge		1 705
Spot with static delta hedge		754.45
Spot with dynamic intrinsic hedge		2 151
Spot with dynamic delta hedge		2 263