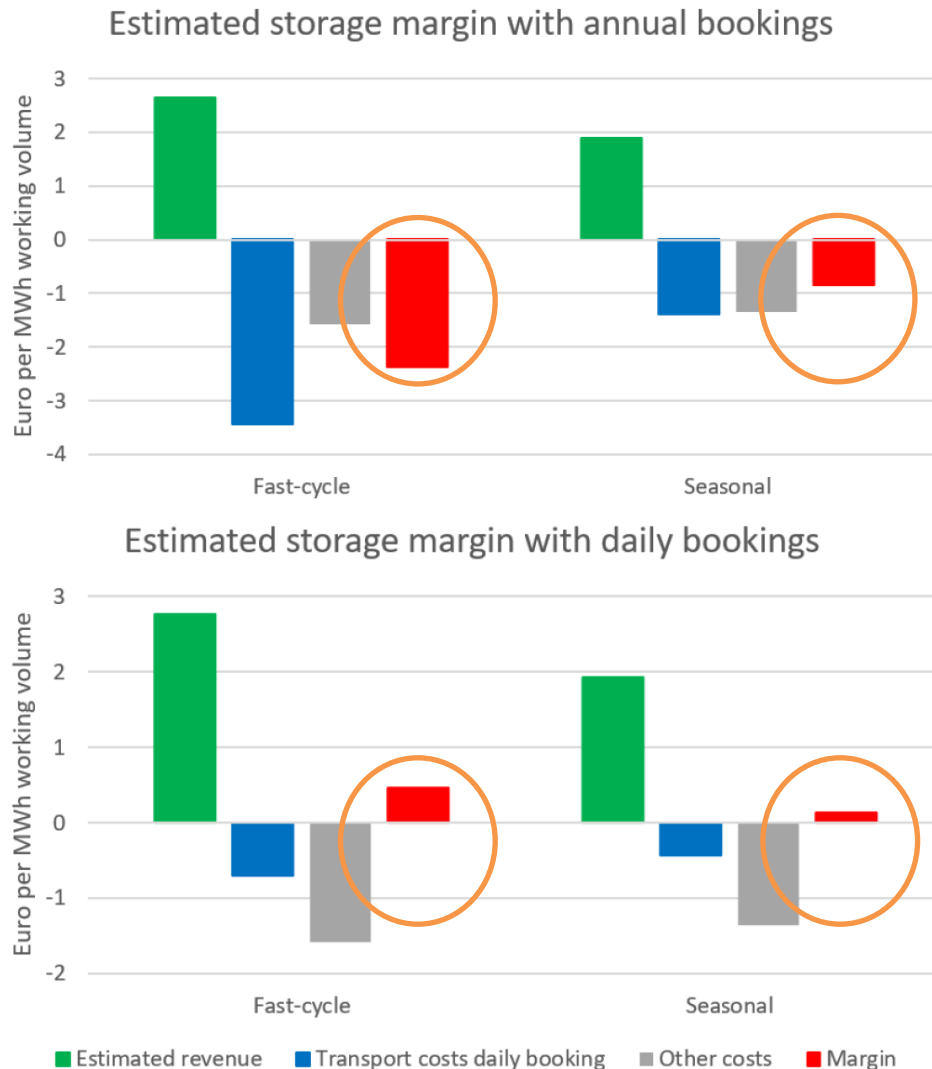


The Economics of Gas Storage

Is there light at the end of the tunnel?



Business case for gas storage in Europe is poor



Reuters headlines:

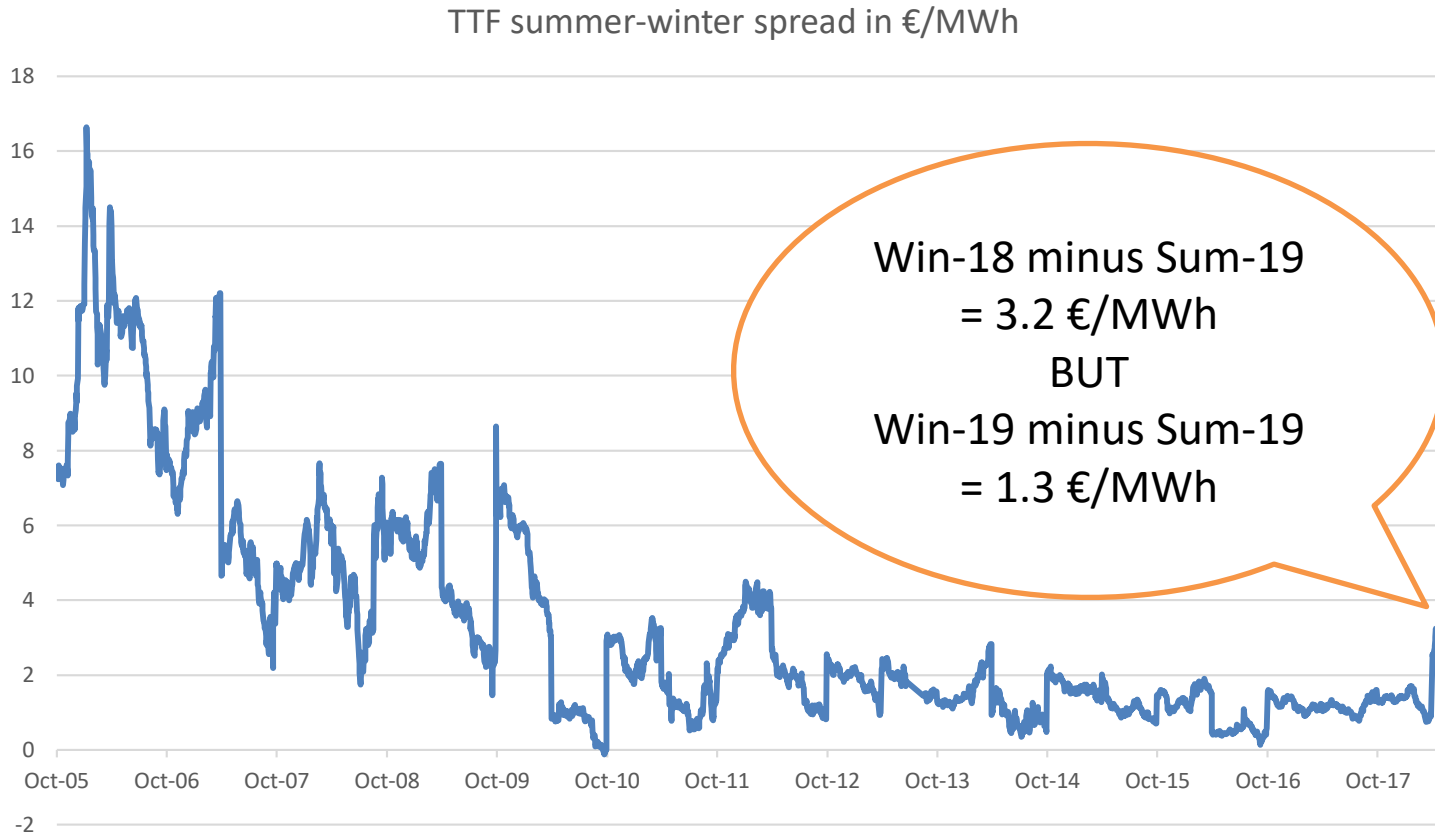
“European utilities are losing billions of euros from gas storage facilities, potentially triggering site closures and divestments in a market suffering from oversupply and weak demand”

KYOS report for Dutch Energy

Market Regulator ACM:

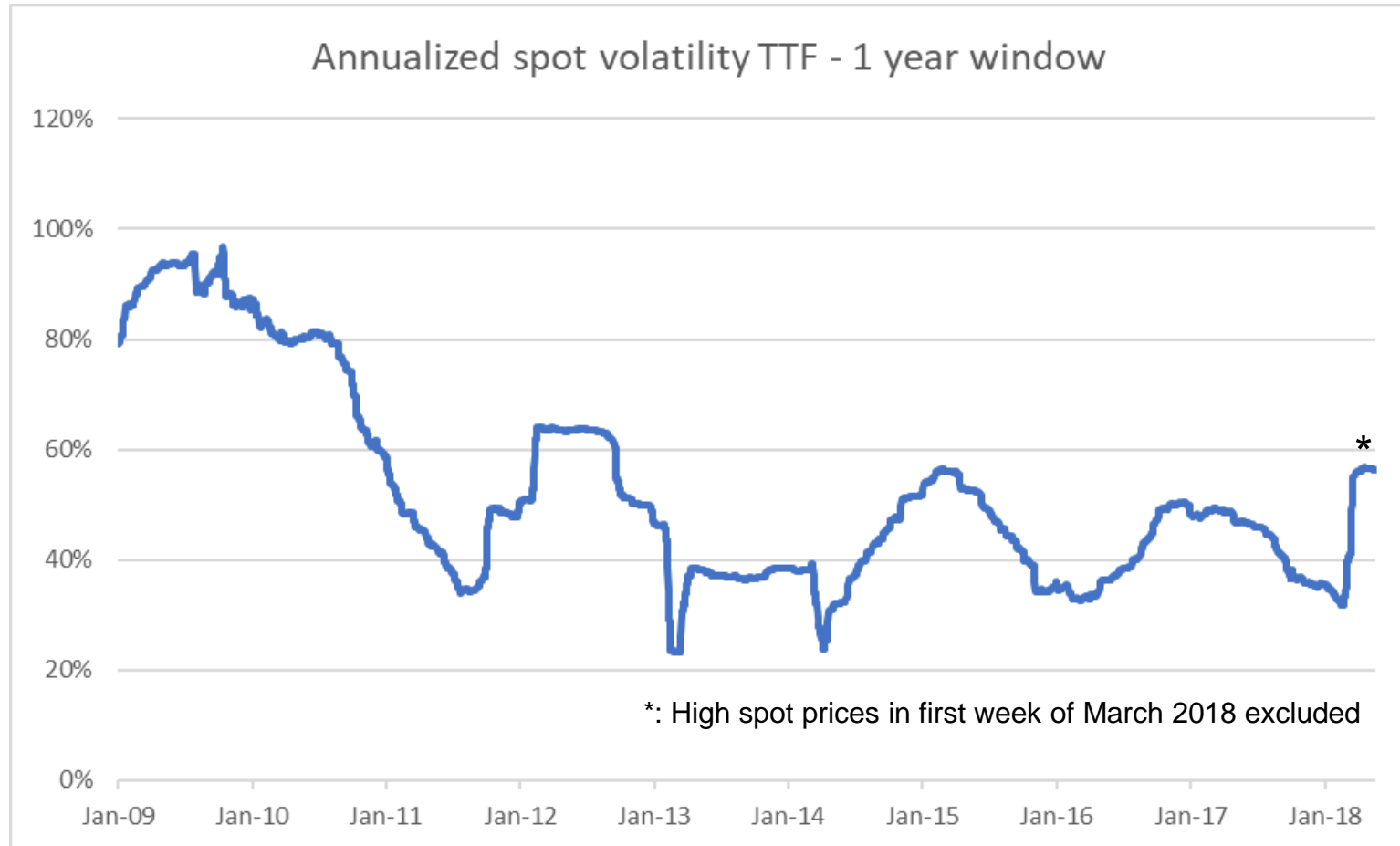
Margins for Dutch storage operators, at current market conditions, are mostly negative

Price driver 1: summer-winter spread



The graph shows the rolling summer-winter spread based on S+1 and S+2. Decline from about 12 to 1-2 €/MWh.

Price driver 2: spot volatility



Decline from about 100% to 40%.

How to assess storage profitability / value?

- Annual reports of storage operators:
 - Billions of euros have been written off
 - Some storage operators report profits, based on old contracts
- Outcomes of storage auctions:
 - Always for specific bundles, not always easy to apply results to other storage bundles
 - Not very transparent
- Broker quotes:
 - Market not so liquid



Analyze storage value with KyStore

Storage valuation approaches

1. Historical: how much could a realistic trading strategy have earned? BACKTEST
2. Future: what is the expected storage value, assuming a realistic trading strategy?

Both approaches assessed with KyStore

Future assessments published monthly

<https://www.kyos.com/gas-storage-swing-report/>

Gas Storage and Swing Report

Storage	Market	Product	Period	Cycle Cost	Intrinsic	Rolling Intrinsic		Option	
						Avg	10%	Avg	10%
	TTF	30/30	SY2019	0.50	1.13 ↑	3.91 ↑	2.65 ↑	5.31 ↑	4.38 ↑
	TTF	60/60	SY2019	0.50	1.13 ↑	2.76 ↑	2.03 ↑	3.52 ↑	2.85 ↑
	TTF	60/120	SY2019	0.50	0.98 ↑	2.21 ↑	1.71 ↑	2.80 ↑	2.31 ↑
	NBP	30/30	SY2019	1.00	9.90 ↑	22.00 ↑	17.43 ↑	24.43 ↑	21.57 ↑
	NBP	60/60	SY2019	1.00	9.90 ↑	16.60 ↑	13.78 ↑	17.87 ↑	16.02 ↑
	NBP	60/120	SY2019	1.00	9.23 ↑	14.08 ↑	12.63 ↑	15.07 ↑	13.42 ↑



#1 in gas storage, swing &
option valuation models

KyStore provides trading signals

What is a realistically optimal storage trading strategy?



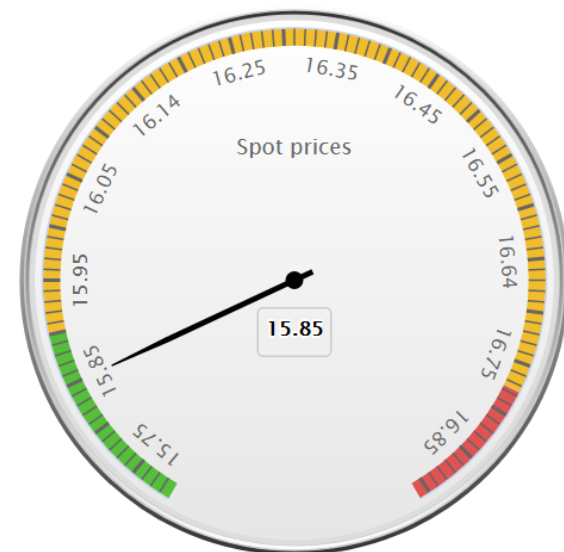
What is a realistic trading strategy?

- Every day, take injection/withdrawal decision based on spot market prices
 - Intrinsic approach OR
 - Option approach = better (Least-squares Monte Carlo)
- In addition, hedge the price exposures in the forward market
 - Intrinsic approach OR
 - Delta hedging = better

Inject below a spot midprice of: 15.90

Withdraw above a spot midprice of: 16.78

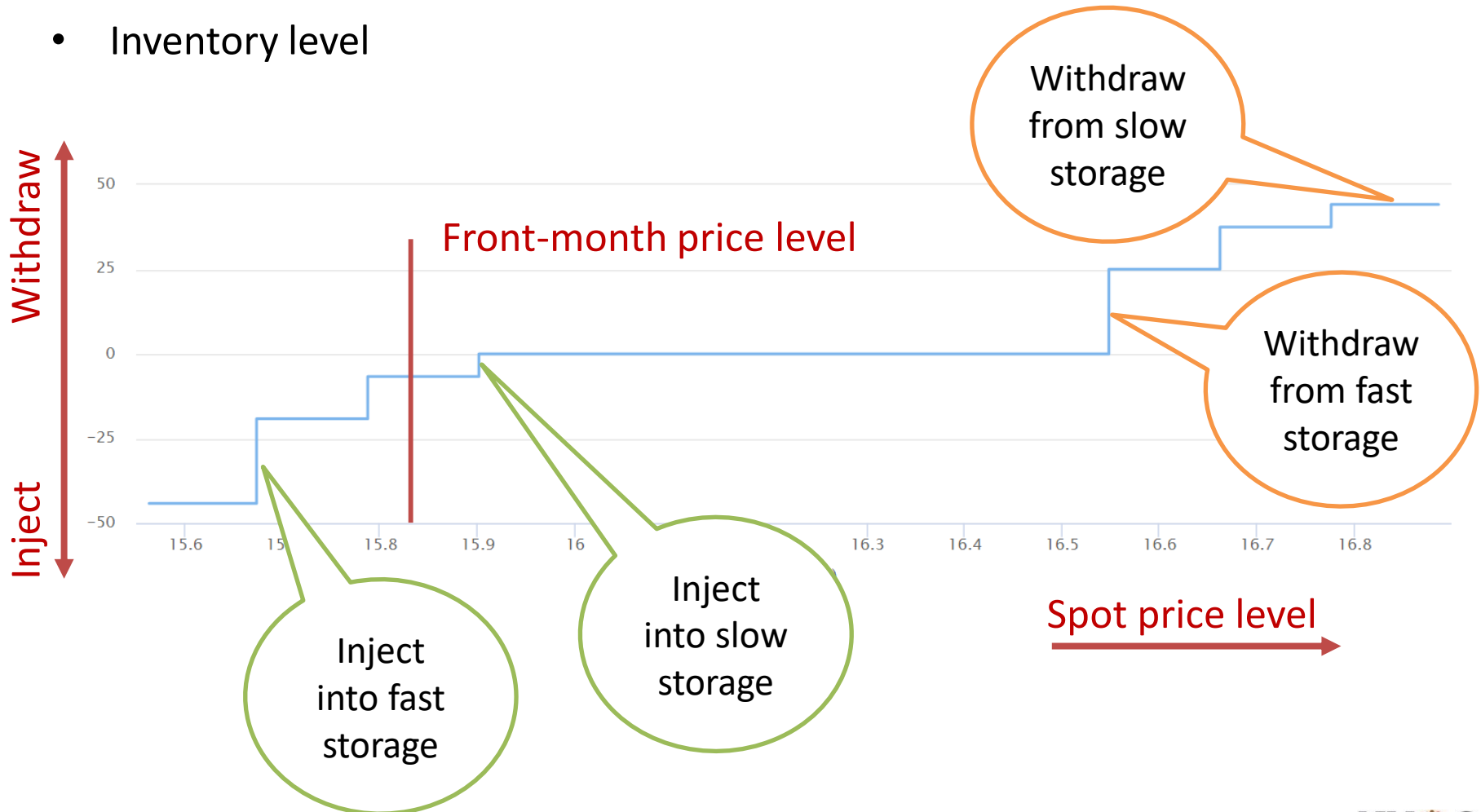
Inject 6.67 MWh.



Example: spot trading signal (portfolio)

3 storage assets, all with different price signals, depending on:

- Market price levels
- Inventory level



Backtest with KyStore

**How much money could have been
made in past years with TTF storage?**



Example backtest SY2017/2018, 60-120 storage

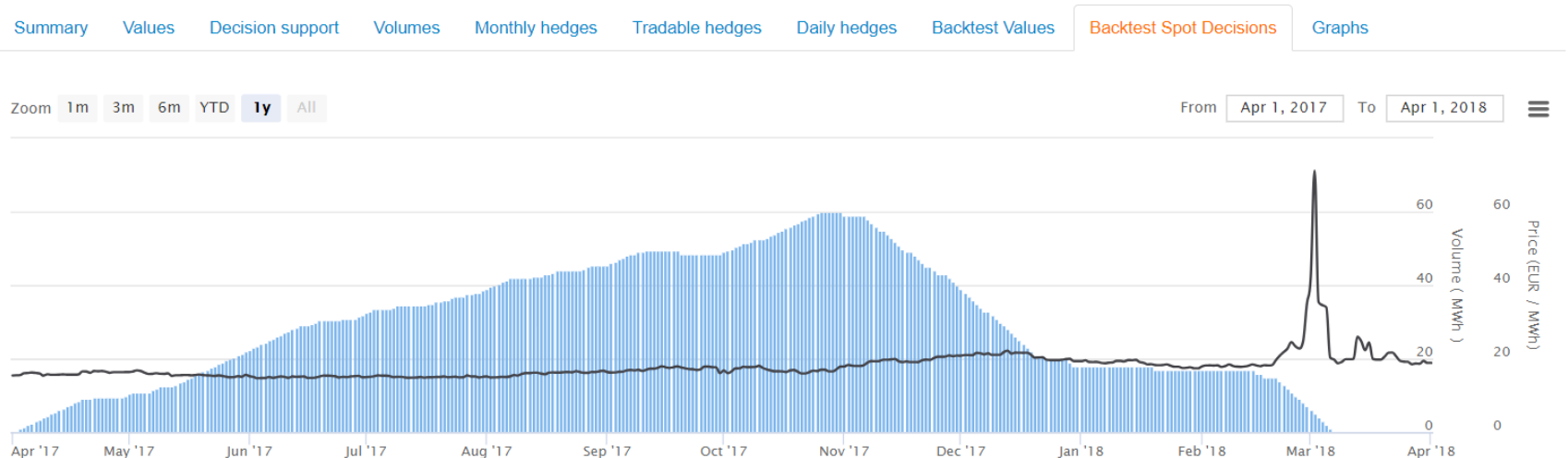
Working volume: 60 MWh
Expected spot trading value: 2.13 €/MWh (127.65 €)
Realized spot trading value: 6.48 €/MWh (388.74 €) -> high winter spot prices
with delta hedging: 2.03 €/MWh (121.54 €) -> **more realistic**

Strategy	Projected value (EUR)	Realized value (EUR)
Intrinsic daily	69.91	
Intrinsic monthly	69.53	
Intrinsic tradable	63.33	
Rolling intrinsic	109.60	81.61
Spot	127.65	388.74
Spot with static intrinsic hedge		153.49
Spot with static delta hedge		222.92
Spot with dynamic intrinsic hedge		70.37
Spot with dynamic delta hedge		121.54

KyStore model
results on actual
price data

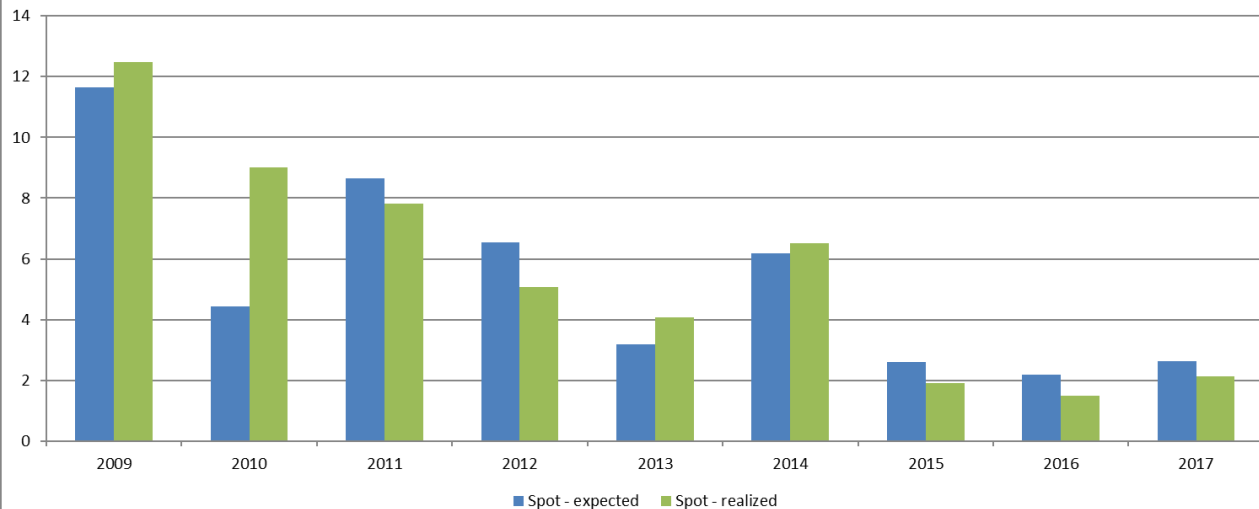
Example backtest continued

- Model finds 'best' days for injection and withdrawal, based on spot and forward prices of that day.
- Model does not know how prices will evolve later on, but generates scenarios to assess optionality
- Prices early winter were not so good, so 1/3 of the gas kept in store until about 20th of February



KYOS backtest results TTF

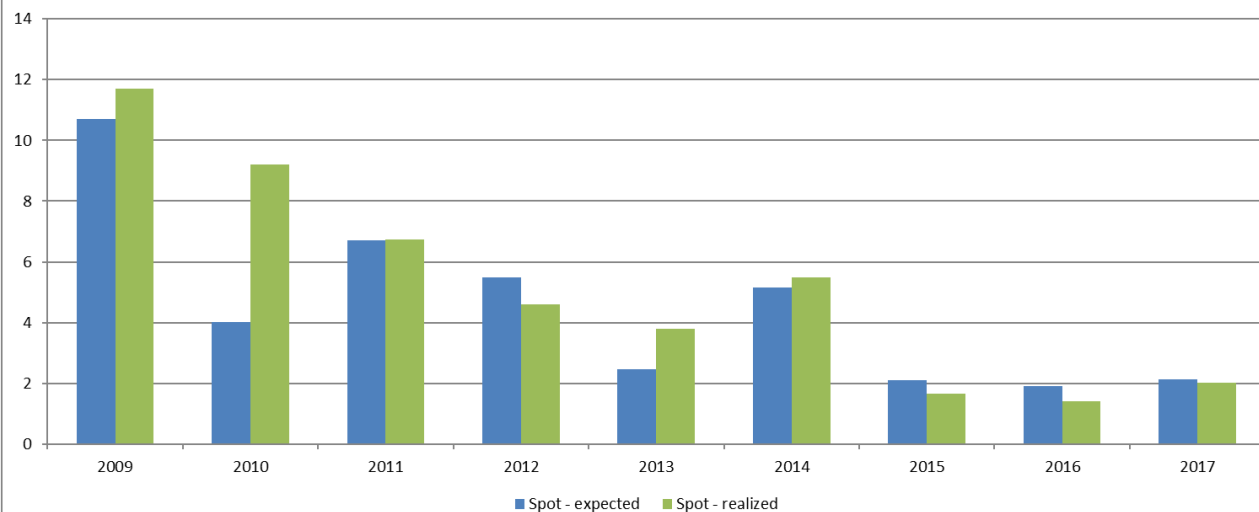
60/60 Storage



60/60 storage:

- Expected: 5.34
- Realized: 5.61

60/120 Storage



60/120 storage:

- Expected: 4.52
- Realized: 5.28

2010 was great, but
last 3 years were tough

Fundamental drivers

What can we expect in the coming years?



What can we expect?

- Supply side:
 - More storage closures in continental Europe +
 - More flex from LNG supplies (or more volatility?) -/+
 - Reduction in production flex (Groningen) +
 - More flexible supplies (Nordstream 2) -
 - Uncertainty around Ukraine as transit route +
- Demand side:
 - Less residential demand (heating, winter) -
 - More (winter) demand from power sector +

Are we close to a positive turning point for storage?

Conclusion

- The past 6-7 years, market conditions for storage have been very poor
- Two weeks of high prices in Feb/Mar 2018 has had limited impact on the market's perception of storage value
- We believe there could very well be some light at the end of the tunnel, especially due to the Groningen closure and coal phase-out
- And: with more optimal trading strategies, more value can be derived from existing storage assets, even in current market conditions

KYOS Energy Analytics

Analytical solutions for trading, valuation & risk management in energy markets

Name	DE Intrinsic €/MWh	DE Simulation €/MWh	UK Intrinsic €/MWh	UK Simulation €/MWh
Coal 46%	3.38 ↑	5.44 ↑	4.93 ↓	6.11 ↓
Coal 46% option	6.18 ↑	7.93 ↑	7.80 ↓	8.78 ↓
Gas 60%	1.12 ↓	3.91 ↑	6.15 ↓	7.11 ↓
Gas 60% option	1.58 ↓	4.27 ↑	6.79 ↓	7.72 ↓

Market	Product	Period	Option 10%	
			Avg	
TTF	30/30	SY2017	3.00 ↓	2.30
TTF	60/60	SY2017	1.92 ↓	1.46
TTF	60/120	SY2017	1.47 ↓	1.11
NBP	30/30	SY2017	18.27 ↑	14.83
NBP	60/60	SY2017	12.90 ↑	10.92
NBP	60/120	SY2017	10.72 ↑	9.12

Power markets

*Power plant optimization, valuation, hedging
Forward curves and Monte Carlo simulations*

Gas markets

*Storage and swing contracts valuation and he
Optimization of gas portfolio assets and contracts*

Multi-commodity portfolio & risk management

*Commodity Trade & Risk Management
At-Risk software: VaR, EaR, CfaR*

www.kyos.com

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