

The Economics of Gas Storage

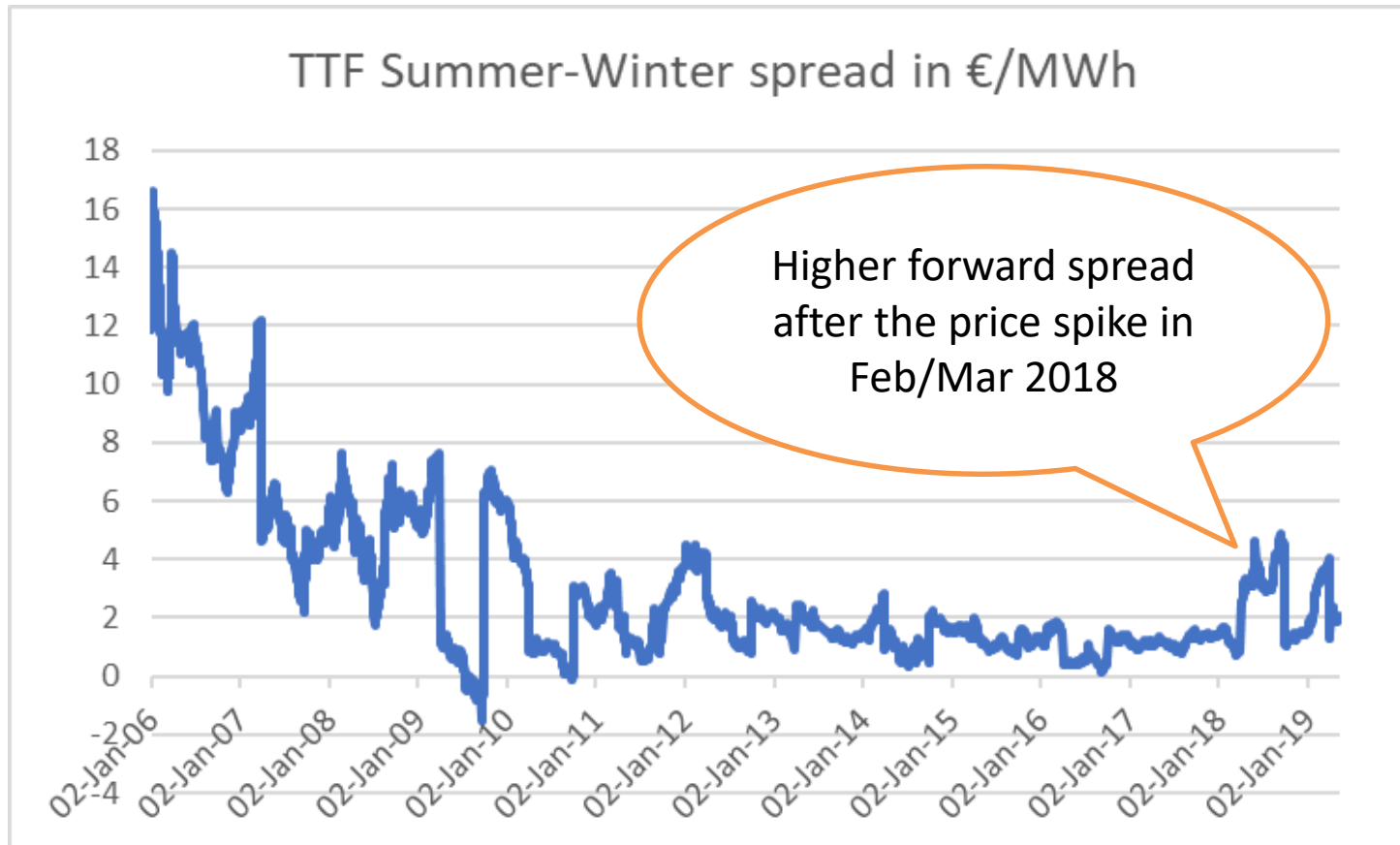
Will volatility come back?



Market trends in storage value

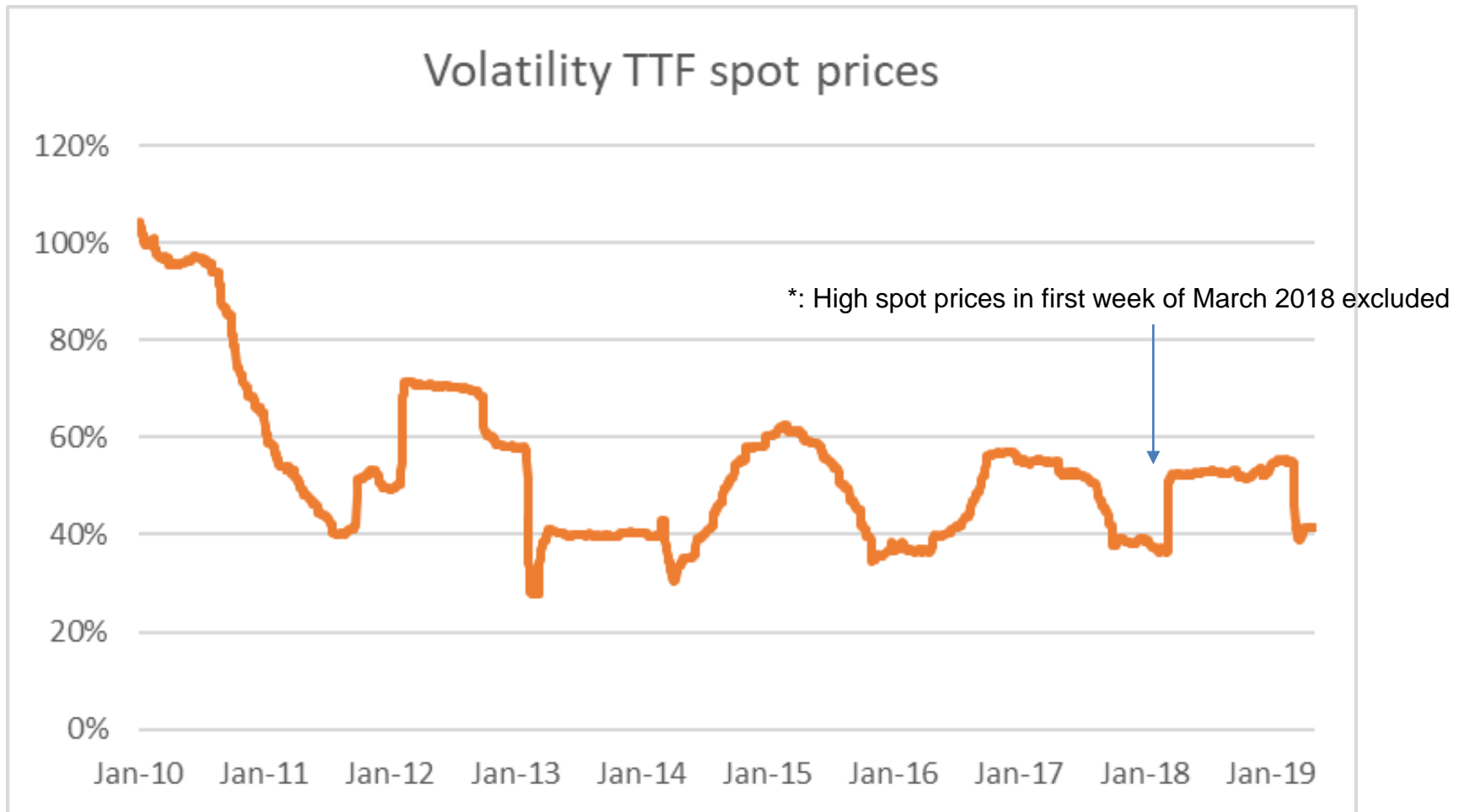


Price driver 1: summer-winter spread



Decline from about 12 to 1-2 €/MWh.

Price driver 2: spot volatility



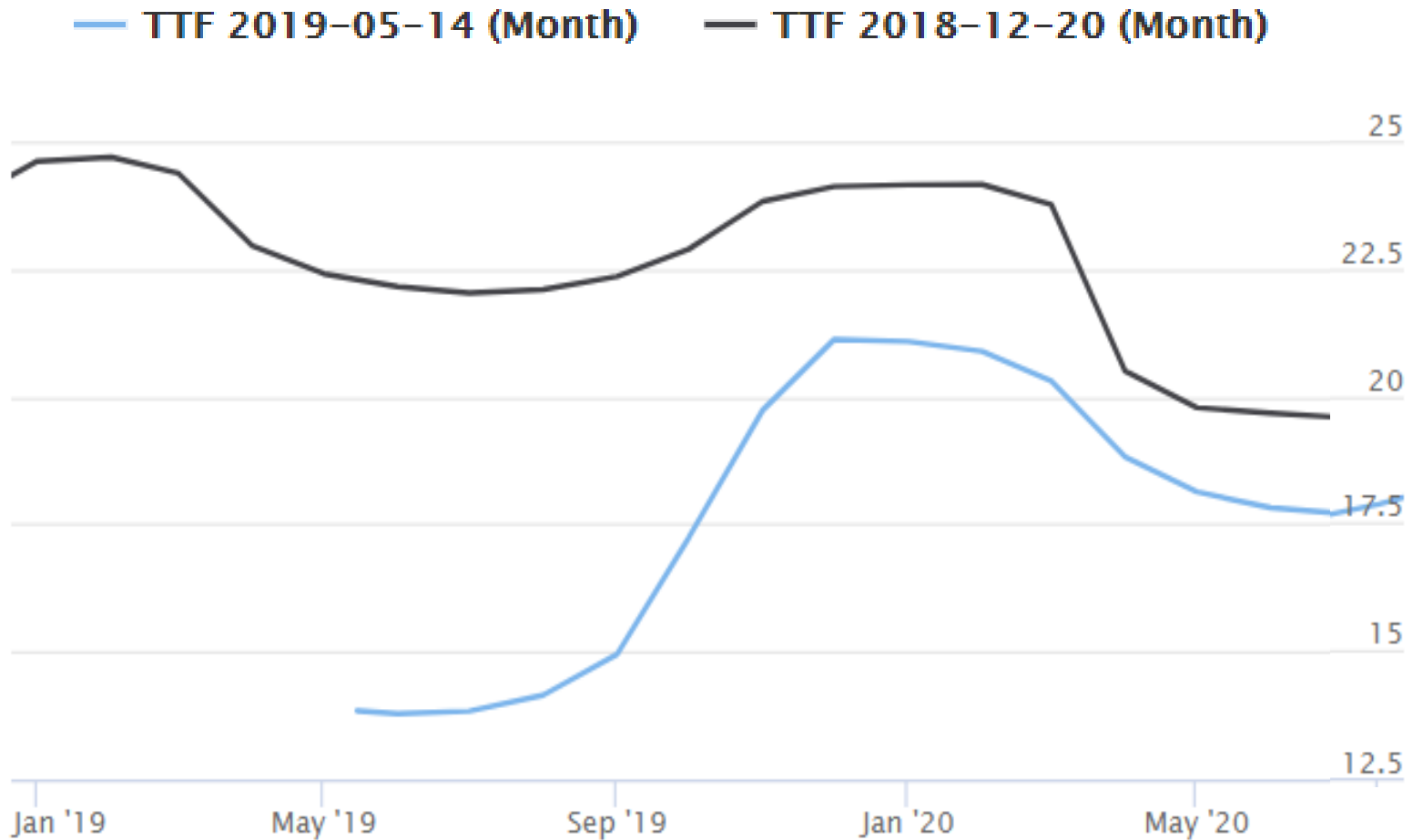
Decline from about 100% to 40%.

Spot prices: will spikes happen again?

- Important to separate the extreme period of Feb/Mar 2018
- Probability that it happens again? 0% or ??



“strange” market conditions after warm winter





#1 in gas storage, swing &
option valuation models

Assessing the value of storage



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 quarterly

Both approaches actively used by traders, structurers, risk managers, project developers, consultants (e.g. in arbitrations)



Gas Storage and Swing Report

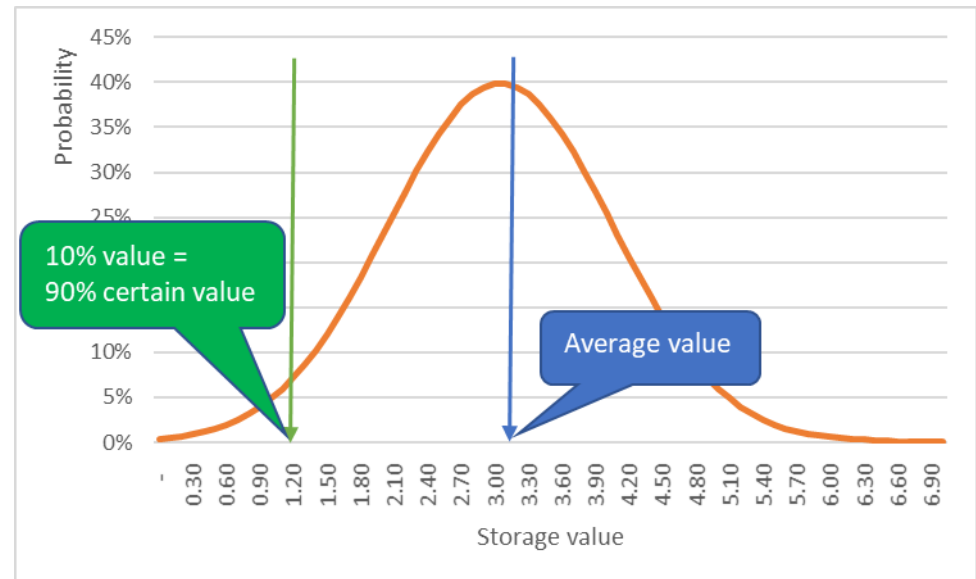
Storage	Market	Product	Period	Cycle Cost	Intrinsic	Rolling Intrinsic		Option	
						Avg	10%	Avg	10%
	TTF	30/30	SY2020	0.50	1.61	3.39	2.63	4.18	3.11
	TTF	60/60	SY2020	0.50	1.61	2.85	2.34	3.57	2.65
	TTF	60/120	SY2020	0.50	1.61	2.60	2.00	3.09	2.43
	NBP	30/30	SY2020	1.00	9.60	19.23	15.83	20.60	17.83
	NBP	60/60	SY2020	1.00	9.60	16.17	14.15	17.07	15.03
	NBP	60/120	SY2020	1.00	9.38	14.83	13.40	13.40	13.55

Swing	Market	Max/day	Min/Max	Period	Price	Intrinsic	Rolling Intrinsic		Option	
							Avg	10%	Avg	10%
	TTF	4	360/360	2020	19.32 ↓	-0.02 ⇔	0.45 ↑	0.18 ↑	0.75 ↑	0.75 ↑
	TTF	1	0/365	2020	19.32 ↓	0.00 ⇔	1.21 ↑	0.30 ↑	1.43 ↑	0.38 ↑
	TTF	4	360/360	2020	MA	-0.02 ⇔	0.63 ↓	0.30 ↓	1.25 ↓	0.70 ↓
	NBP	4	360/360	2020	58.38 ↓	-0.02 ⇔	1.65 ↑	0.51 ↑	2.15 ↑	0.20 ↑
	NBP	1	0/365	2020	58.38 ↓	0.00 ⇔	2.98 ↓	0.45 ↑	3.10 ↑	0.79 ↑
	NBP	4	360/360	2020	MA	-0.02 ⇔	2.38 ↓	1.22 ↓	3.76 ↓	2.29 ↓

Short explanation of trading methodologies

- Rolling intrinsic:
 - First lock in the intrinsic value (initial forward hedges)
 - Then every day, adjust forward hedges (incl spot) for extra trading profit
- Spot = Full option:
 - Maximize value by trading in the spot market
 - Delta hedge exposures in the forward market

Spot and rolling intrinsic value are derived from Monte Carlo price simulations (forward and spot)



Backtest with KyStore

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



Example backtest SY2018/2019, 60-60 storage

Working volume: 60 MWh
Trading strategy: spot trading with rolling intrinsic
Expected value: 1.88 €/MWh (112.98 €)
Realized value: 2.31 €/MWh (138.63 €)

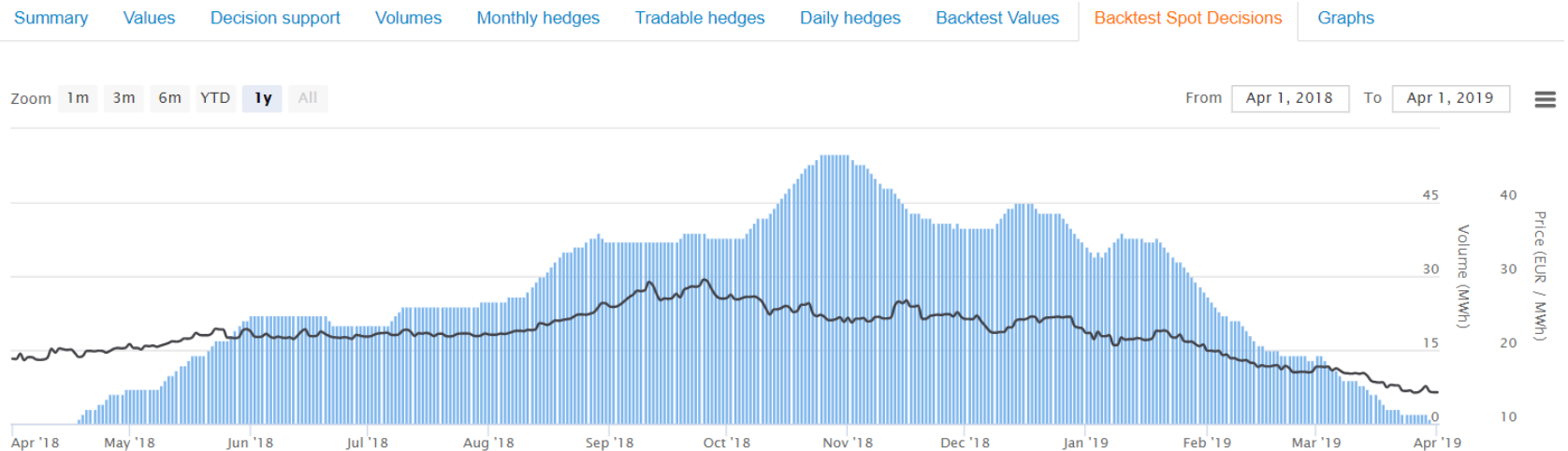
KyStore model
results on actual
price data

Backtest Values

Strategy	Projected value (EUR)	Realized value (EUR)
Intrinsic daily	53.75	
Intrinsic monthly	48.46	
Intrinsic tradable	39.08	
Rolling intrinsic	112.98	138.63

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; different hedging strategies possible (intrinsic, delta)
- Very difficult to make money in SY18/19 due to low volatility and low winter prices



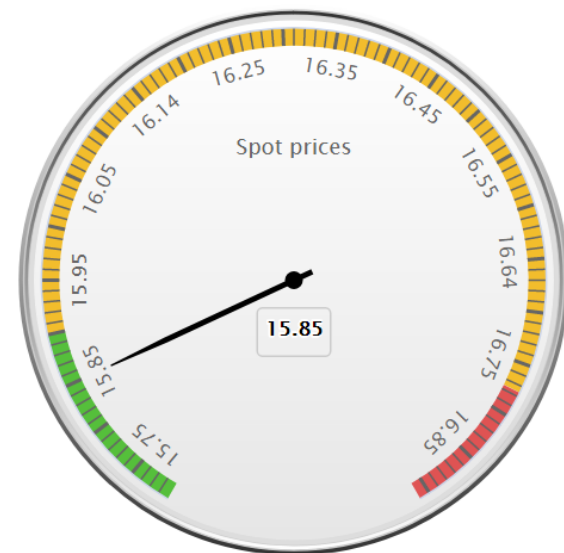
What is a realistic trading strategy?

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

Inject below a spot midprice of: 15.90

Withdraw above a spot midprice of: 16.78

Inject 6.67 MWh.



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?

Growth in renewable production

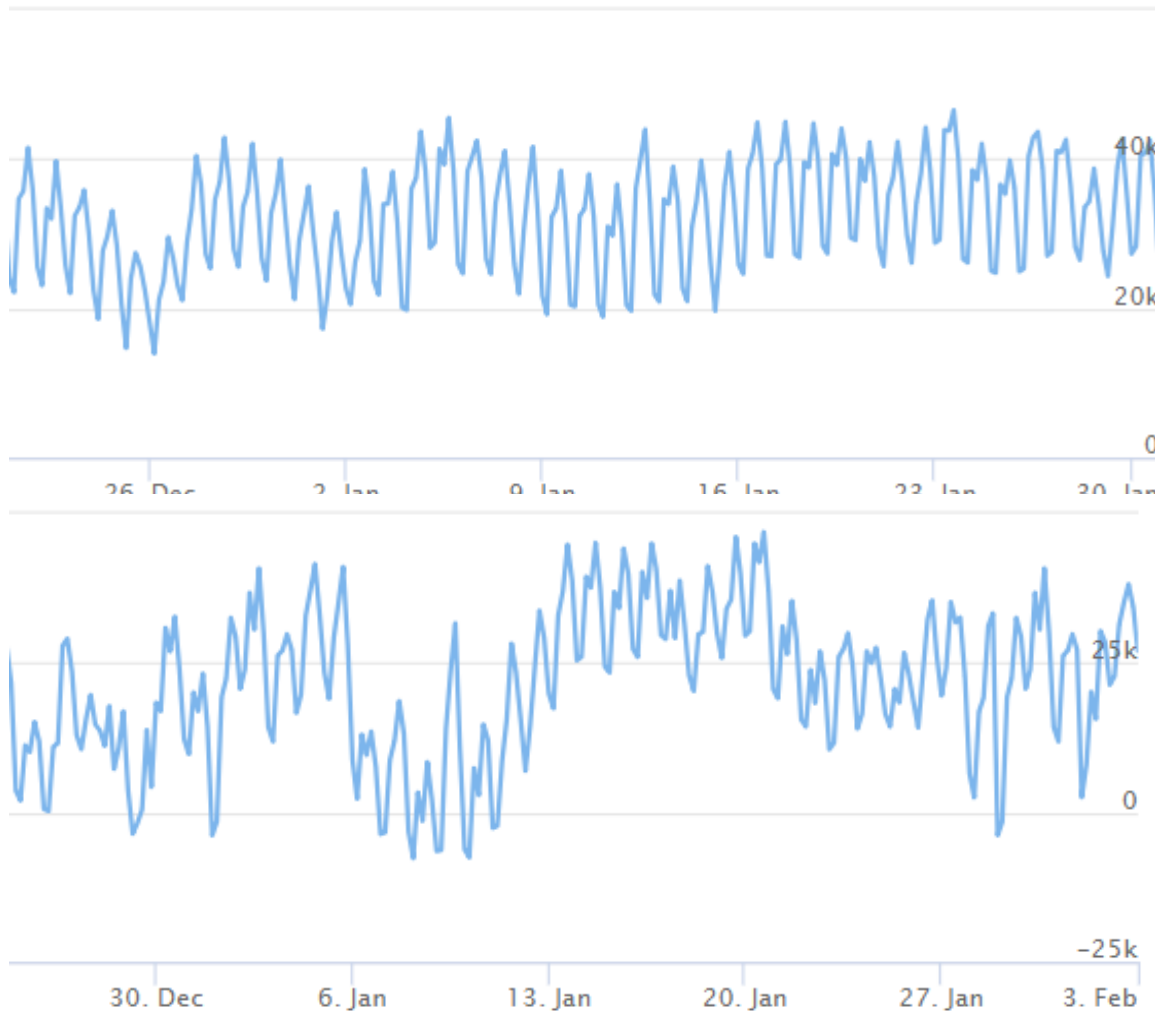
- Table shows combined GW capacities in DE+AT, FR, NL, BE, GB
- Lignite, coal, oil and nuclear will gradually be reduced
- Gas + biomass have to fill part of the gap (KYOS assumption)

TOTAL PLANT CAPACITIES

	2017	2030
Natural gas	93	107
Hard coal	43	21
Lignite	20	6
Biomass	10	25
Nuclear	88	52
Oil	10	7
TOTAL	264	218

Residual load patterns will change

GB market: 2030 forecast versus 2017 (6 weeks around New Year)



2017

Predictable pattern between 20 and 40 GW, driven by demand

2030

Very volatile pattern between -10 and 45 GW, driven by renewable production (wind mainly)

Conclusion

- 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
- Market conditions can improve in 3-5 years, especially due to the coal phase-out and re-activation of gas-fired power plants, combined with some storage closures
- And: with more optimal trading strategies, the maximum value can be derived from storage 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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