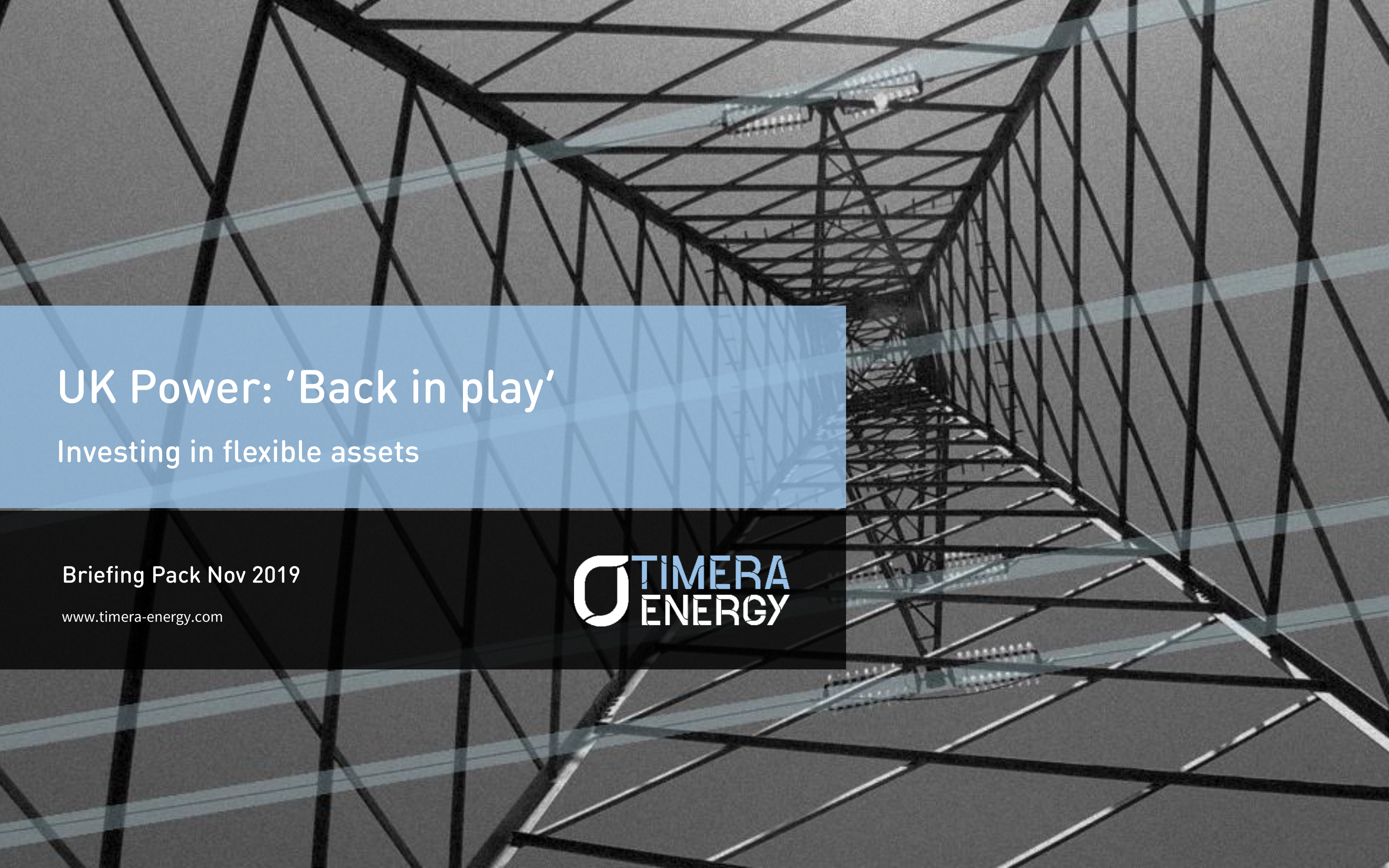

UK Power: ‘Back in play’

Investing in flexible assets

Briefing Pack Nov 2019

www.timera-energy.com

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Contents

Flex asset investment
5 considerations

1. **Investment case** for flexible capacity (e.g. batteries, engines, DSR & CCGTs) is built on a viable revenue stack.
2. **Capacity Market** is now 'back in play', with key auctions in Q1 2020 set to shape the UK capacity mix into mid-2020s.
3. **Capacity prices** may surprise to the upside given structural tightening in UK capacity balance as coal, CCGTs & nukes close & capacity bids rise.
4. **Spot price volatility & price shape** are rising as wind & solar output increases and the UK supply stack steepens.
5. **Revenue stacks**, value drivers & risk profiles vary significantly by capacity type – we show stacks for batteries, engines, CCGTs & interconnectors.

Kay revenue stack components & value drivers

Revenue Stack	Description	Drivers
Capacity Market (CM)	• Stable cashflow for up to 15 years • Underpins any leverage opportunity	• System capacity margin • Technology de-rating factor • Contract length
Wholesale & Balancing Market (BM)	• Forward mkt hedging • Spot optimisation • Additional BM re-optimisation value	• Forward price • Spot price shape • Spot & BM price volatility
Balancing Services	• Frequency Response, Fast Reserve, STOR, Black Start	• Changing capacity mix • System constraints

Source: Timera Energy

Capacity Market is back

Capacity Market is back

- Re-instated in Oct-19, with immediate resumption of payments.
- Payments cover both on-going and historical capacity provided.
- EC found no evidence of discrimination against DSR, so no changes to existing CM required.
- 3 auctions across 5 weeks in Q1-2020.
- T-3 & T-4 auctions important in shaping UK capacity mix into mid-2020s.

Q1 2020 auctions

Auction	Date
T-3 2022-23	30 Jan 2020
T-1 2020-21	06 Feb 2020
T-4 2023-24	05 Mar 2020

Wind & solar in the CM

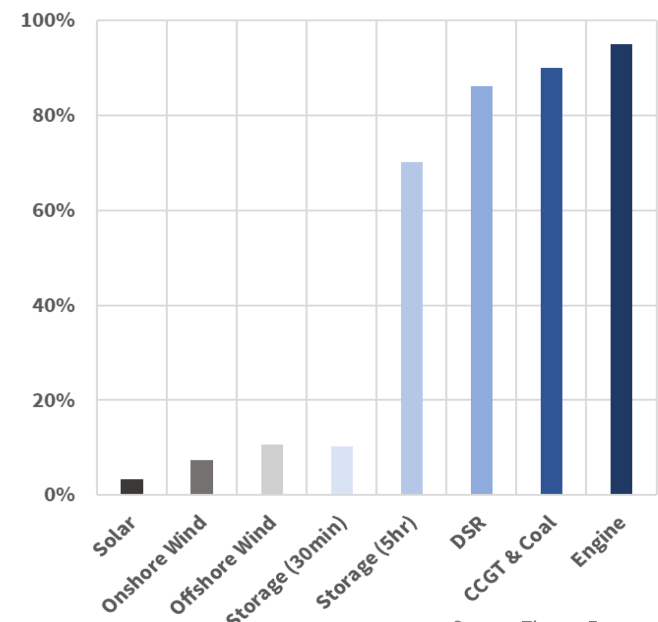
- From Jan-20 onwards, wind & solar can participate (provided no other support received e.g. CfD, RO).
- But… heavy de-rating factors apply (see right).
- CM inclusion is relevant for (i) older RES capacity with existing support mechanism expiring and (ii) merchant RES.

De-rating factors & illustrative revenues

Technology	Derating %	Revenue £/MW/yr
CCGT	90.0%	7560
Battery – 0.5hr	10.2%	858
Battery – 5hr+	95.1%	7987
Wind Onshore	7.4%	623
Wind Offshore	10.6%	886
Solar	3.2%	270

Revenue figures are illustrative & calculated using latest T-4 capacity auction price.

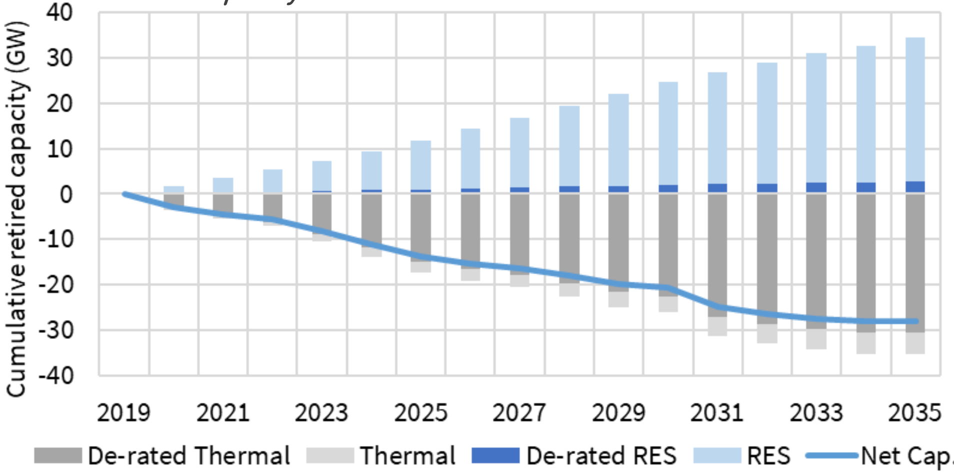
T-4 de-rating factors by capacity type



Source: Timera Energy

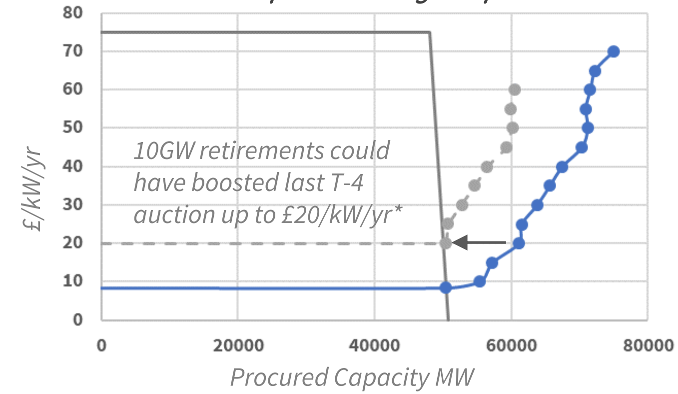
25-30GW of flex capacity needed in 2020s

UK net capacity deficit – RES build vs thermal closures



Source: Timera Energy

CM bid stack points to higher prices



*Illustrative analysis based on last T-4 capacity auction bid strategies

Source: Timera Energy

Driver	Detail	Impact
Coal phase out	Coal capacity to fall 40% by Oct-2020 & disappear by 2025 (if not by 2023-24).	Bullish
Gas retirement	3-5 GW of older & less flexible CCGTs to close by mid 2020s, 8-12 GW by 2030.	Bullish
Nuke closures	4 GW nuclear scheduled to retire by 2025 (delays?). Risk to Hinkley Point C completion date.	Bullish
Renewable participation	Wind & solar derating factors limit impact of RES on capacity price. For every 1GW of coal retirement, 27GW of solar or 8GW of offshore wind required.	Neutral
Storage derating	Short-duration batteries heavily de-rated & therefore limited impact on capacity price. Competitiveness of longer duration batteries into mid-2020s not yet clear.	Unclear

Capacity prices set to rise

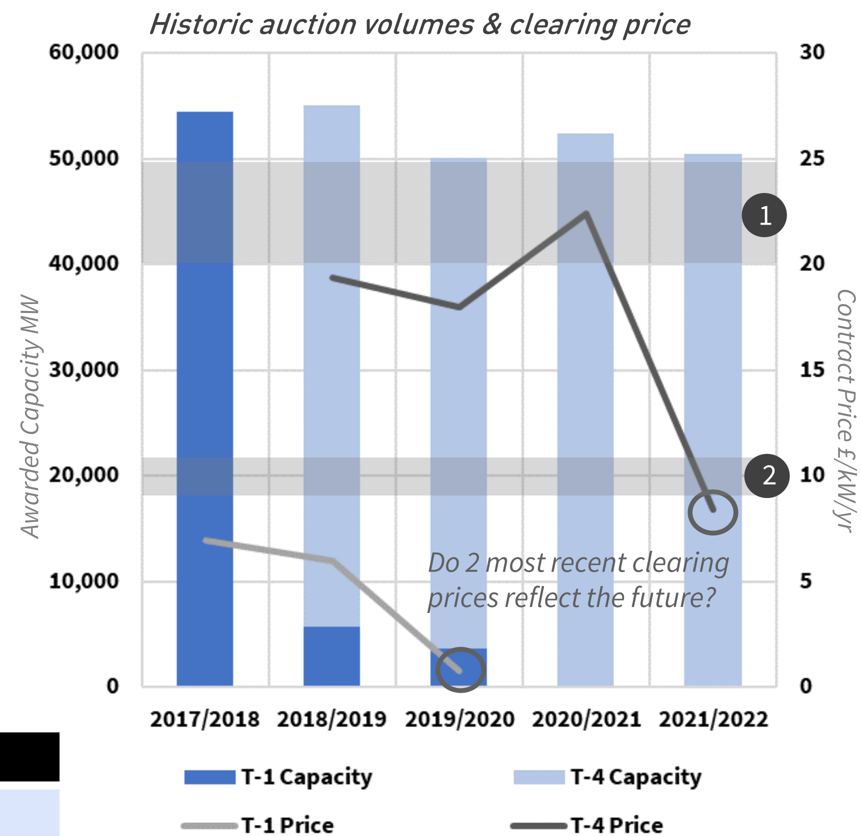
Market consensus for weak prices

- Last two auction results are driving weaker consensus price expectations. But does this make sense…?
  - 0.77 £/kW T-1 price in 2019 was essentially irrelevant given very short lead time to respond (3.5 months)
  - £8.40/kW T-4 price in 2018 reflected a fundamentally different set of expectations to today (see table below).

Factors supporting higher bids this time

- DSR played a big role in last T-4 auction but is handicapped going forward by Transmission Charging Review (TCR).
- Weak returns across 2018-19 have pulled down gas engine revenue expectations, supporting capacity bids in 2020.

Driver	Factors supporting higher bids
Engines	Revenue revisions given weak returns across 2018-19
DSR	Penal TCR ruling (& weak returns) undermining revenue
Batteries	Focus remains on short duration with high derating
CCGTs	Increasing decarbonisation tail risks (need 20-25 £/kW+)
I-connectors	Falling intrinsic price spreads e.g. UK vs FR/DE/BE/NL



1 ***Soft upper bound:*** *New build CCGTs likely to cap structural price rises above 25 £/kW*

2 ***Soft lower bound:*** *Existing CCGT closures likely to limit structural price declines below 10 £/kW*

Source: Timera Energy

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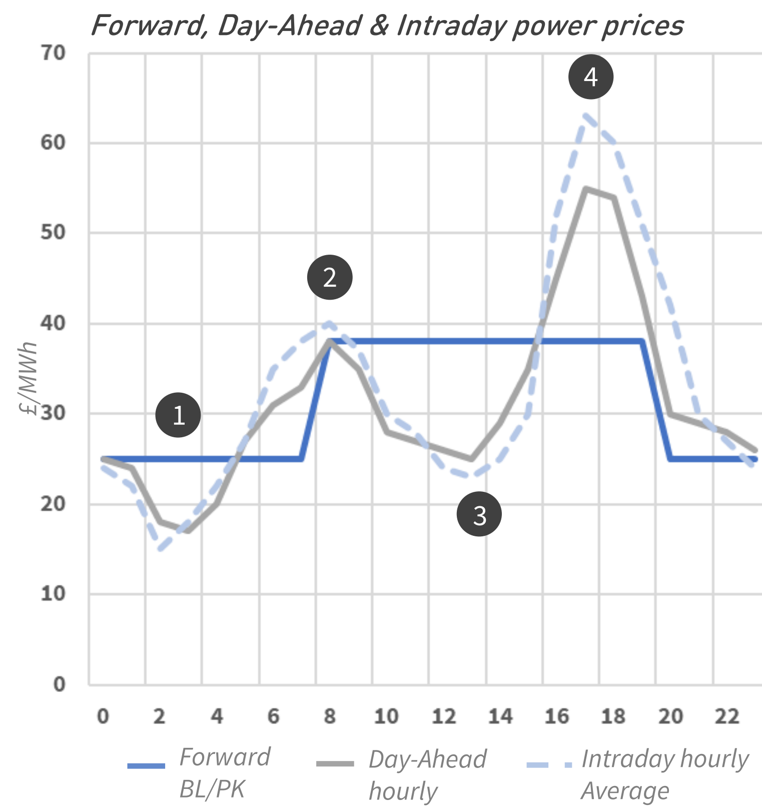
Spot price signal trends support flex value

Structural trend: Spot price shape and volatility to increase across 2020s

	Period	Current drivers	Future drivers
1	**Overnight**	• Overnight two-shift pricing of CCGT • Wind generation	• Increasing CCGT efficiency • Increasing wind • Loss of baseload nukes
2	**Morning pick up**	• CCGT start-ups	• Range of pick up to increase as nuclear retires
3	**Solar dip**	• Solar eating into demand • CCGT incremental costs	• More day-on-day variability as solar output rises • Smart devices shift load?
4	**Evening peak**	• GT/engine costs • Storage (shape dependent) • Interconnectors • Wind generation	• Price to become more volatile as stack steepens • Smart devices shift load?



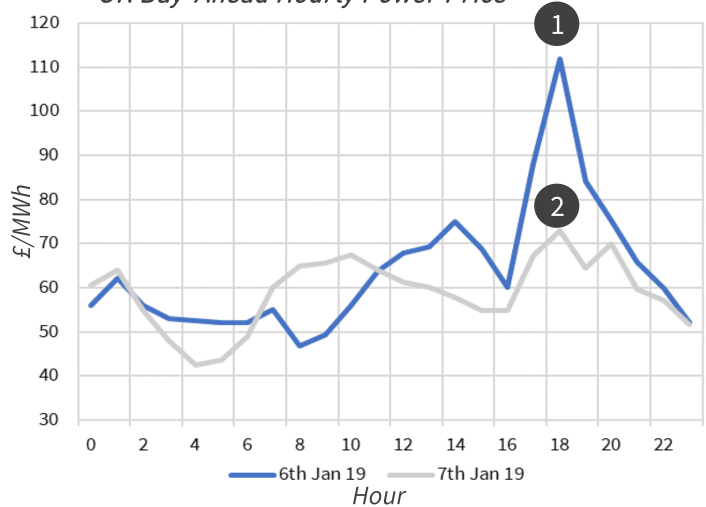
Source: Timera Energy

Spot volatility already rising

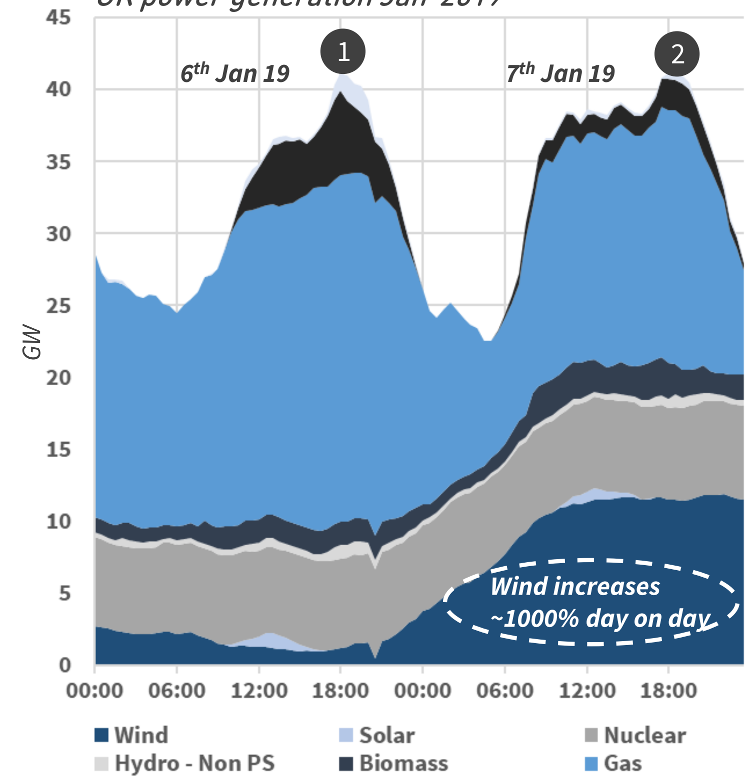
Current reality: renewables are already driving spot volatility

	Date	Demand	Thermal generation	Wind generation	Price 18:00
1	**Sun 6th Jan 19**	43GW	38GW	1GW	£112/ MWh
2	**Mon 7th Jan 19**	43GW	27GW	11.5GW	£73/ MWh

UK Day-Ahead Hourly Power Price



UK power generation Jan-2019

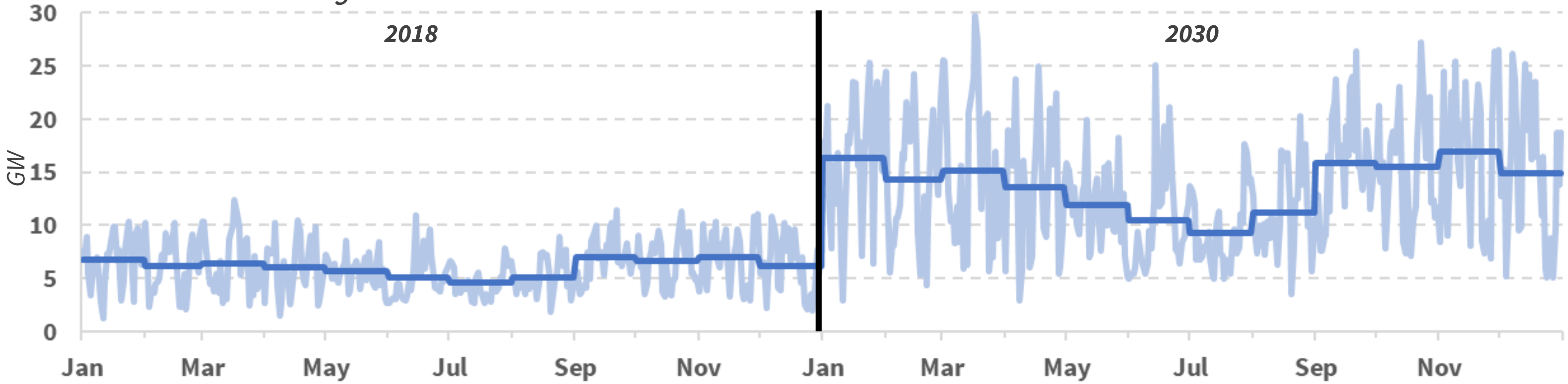


***Case study from Jan-2019** illustrates how renewable intermittency is already a significant source of spot price volatility in the UK. 10GW day on day wind generation increase across the evening peak caused prices to fall by almost 40 £/MWh.*

Source: Timera Energy

Spot volatility to continue uptrend

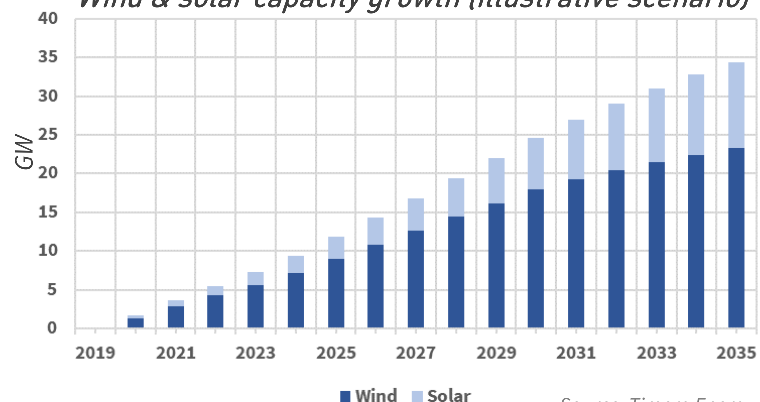
UK wind and solar generation



Impact calculated using historical load factors against capacity growth forecast. Peak hour winter demand assumed at 50GW.

Driver	Impact	% of peak demand
Wind capacity to reach 40GW by 2030	Day-on-day swings in generation to reach 19GW	38%
Solar capacity to reach 20GW by 2030	Within-day swings to reach 12GW	24%
Nuclear retirement	Removal of baseload generation	16%

Wind & solar capacity growth (illustrative scenario)



Source: Timera Energy

Steepening stack supports volatility

Supply stack steepening at both ends

- Peaking assets steepen the slope on the right hand side of the supply curve (e.g. engines, GTs, DSR).
- Retirement of coal, CCGTs & nuclear shifts whole stack to the left.
- Two factors combining to drive volatility:
    1. Rising wind & solar cause greater fluctuations across stack over time
    2. Steeper stack drives greater price swings

Simple fact - conventional stack modelling undervalues flexible capacity!

- Multiple (e.g. 500+) stochastic simulations of correlated wind, solar & load profiles are required to properly value flexible assets.
- Stochastic stack modelling is key to generating robust distributions of power prices, capturing price shape & volatility.
- The true value of flexible capacity is its ability to respond to price shape & volatility.

*Dispatchable winter supply stack, 2020 vs 2030**

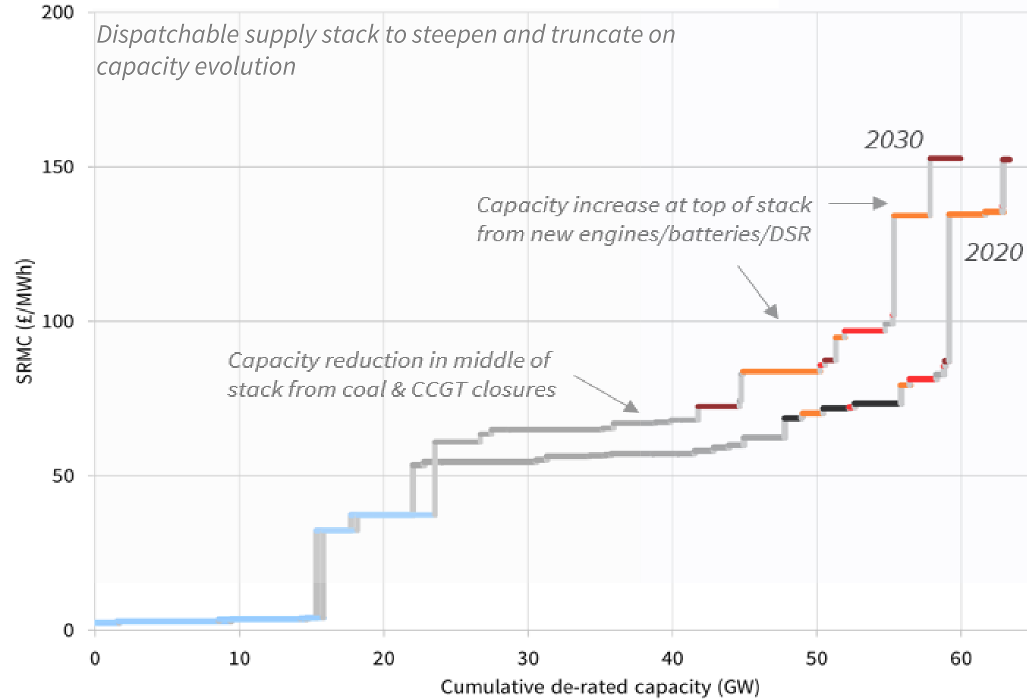


**Chart shows dispatchable supply stack (i.e. includes biomass, nuclear, gas, coal and storage but excludes wind & solar).*

Source: Timera Energy

Stochastic stack modelling insight

The chart illustrates insight into evolution of UK pricing dynamics that can only be gained via stochastic modelling.

A. Peak prices rise & more volatile

- Coal/CCGT closures pulling new peaking flex sources onto the margin (engines, batteries, DSR).
- Variable cost of this new peaking flex is higher, lifting peak prices.
- Peak price shape changing with (i) shifting load shape & (ii) intraday wind/solar profiles.

B. Offpeak prices fall & more volatile

- Higher wind & solar output swings (zero/negative SRMC) drag down offpeak prices.
- Gas price linkage remains important, but is gradually eroded over time.

Evolution of marginal price setting units (2020 – 30)

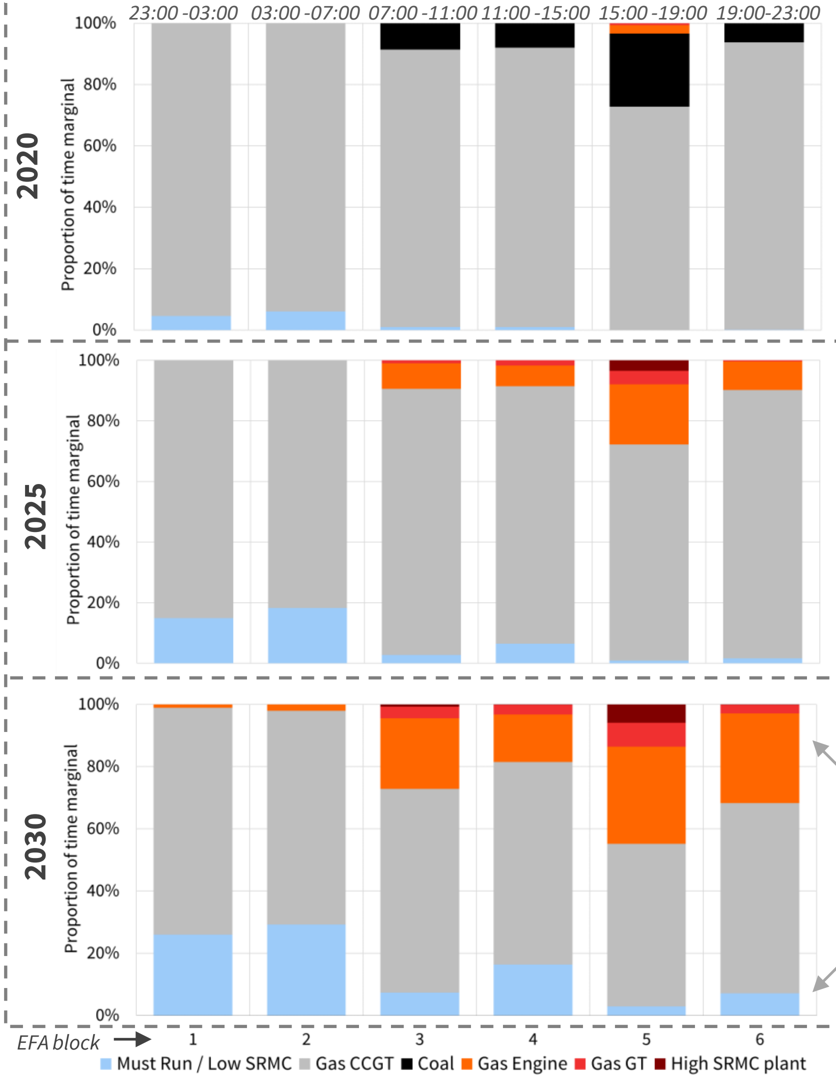


Chart shows the % of time different technology types set power prices across the day.

Analysis is built on a distribution of projected wind & solar output.

CCGTs dominate marginal price setting.

In periods of low wind & solar and high demand, peaking capacity sets prices.

In periods of high wind & solar and low demand, must run capacity sets prices (at low or negative levels).

Higher variable cost engines, batteries, GTs, DSR lifting peak prices.

Low variable cost wind & solar pulling down offpeak prices.

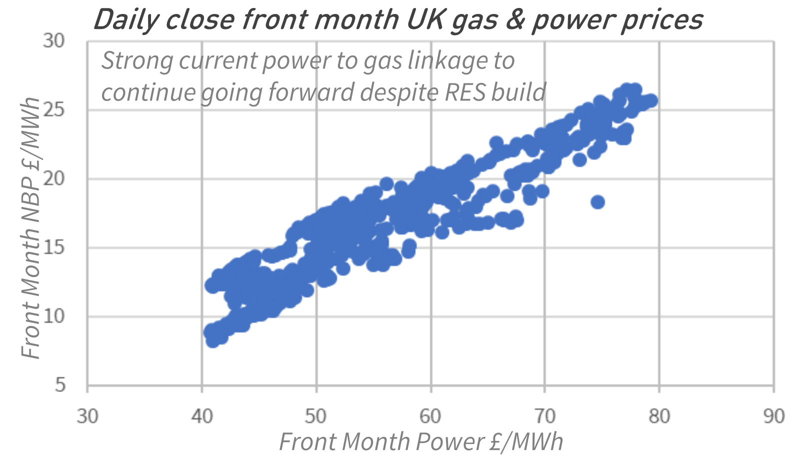
Source: Timera Energy

Note: scale of impacts depend on evolution of capacity mix & demand e.g. more peaking flex vs CCGTs increases A. More wind & solar increases B, decreases A.

Forward price drivers: gas key

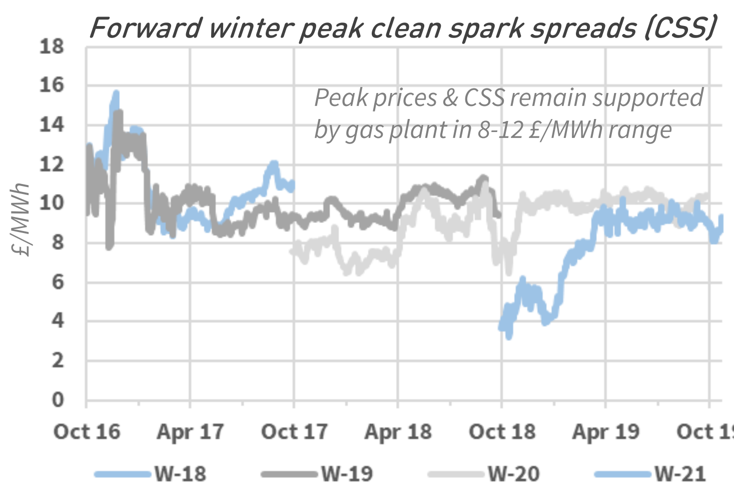
Gas price link: *'reports of the death of power to gas price linkage are greatly exaggerated…'*

Driver	Impact	Evolution
Gas Price	**High**	• Gas-plant set to remain dominant marginal price setting capacity well into 2030s… even in the case of very high wind & solar build scenario • Gas linkage to strengthen as coal retires • But… wind & solar to steadily erode offpeak prices & CSS • Peak prices & CSS to remain supported by requirement for gas plant flex • Batteries 'shadow price' to gas
Carbon Price	**Medium**	• System carbon intensity to fall (coal retirement & renewable build) • Significant policy uncertainty remains as to UK carbon price floor (+ Brexit impact)
Coal Price	**Low**	• Retirements remove coal linkage (peaks) • But coal still important via EU switching dynamics & impact on gas price levels



Daily close prices for front month NBP and UK Power baseload contract since Jan-2017

Source: Timera Energy



Forward winter NBP, UK PK power, API2 and Dec EUA contracts, assuming 49.13% HHV

Balancing Mechanism value

BM to dominate engine & battery value capture

- Engine & battery value capture strategies are currently focused on cashout (NIV) chasing & triad revenues.
- This is set to transition to BM value capture over next 3 years (risk/return & policy drivers).

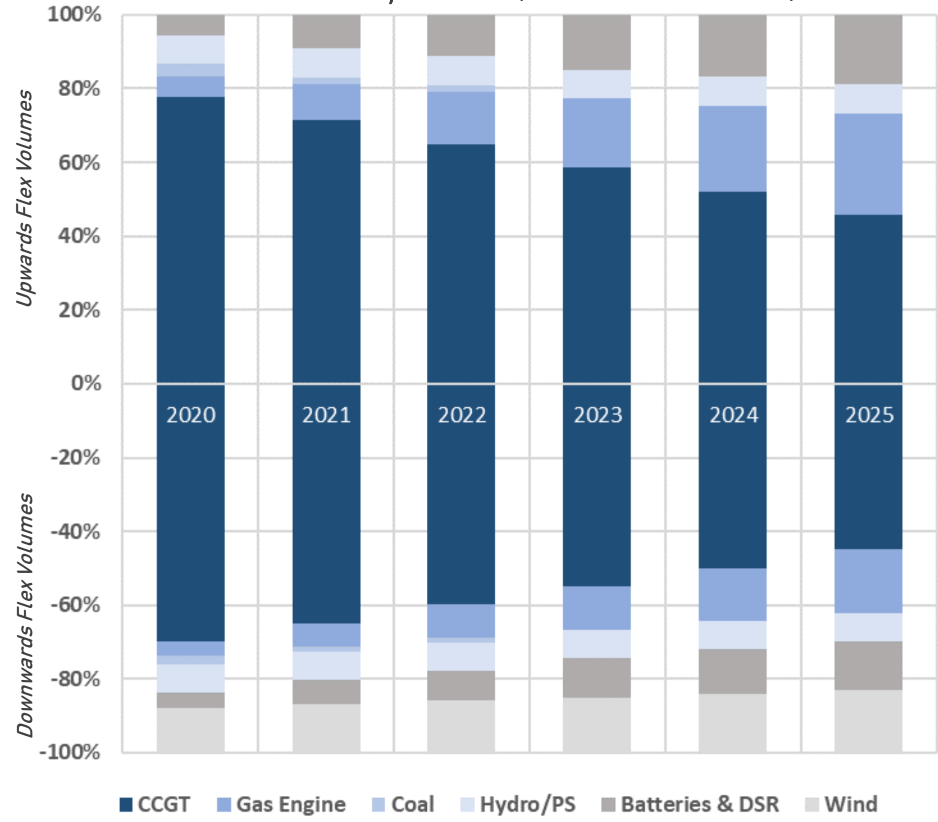
BM value driver evolution

- CCGT & coal assets currently dominate BM flex.
- But… these are set to lose market share to new peaking flex e.g. batteries, engines (see chart).
- Wind will also provide important downward flex, particularly to alleviate constraints.
- Rising wind & solar output swings will increase BM volume & value substantially across 2020s.

BM value requires sophisticated analytics

- Challenge for flex assets → BM revenues are pay-as-offer i.e. participants face substantial volume risk.
- Valuation of engines & batteries needs to reflect practical impact of BM trading strategy on value capture… '*theoretical modelling → theoretical value*'.

Evolution of BM flex provision (illustrative scenario)

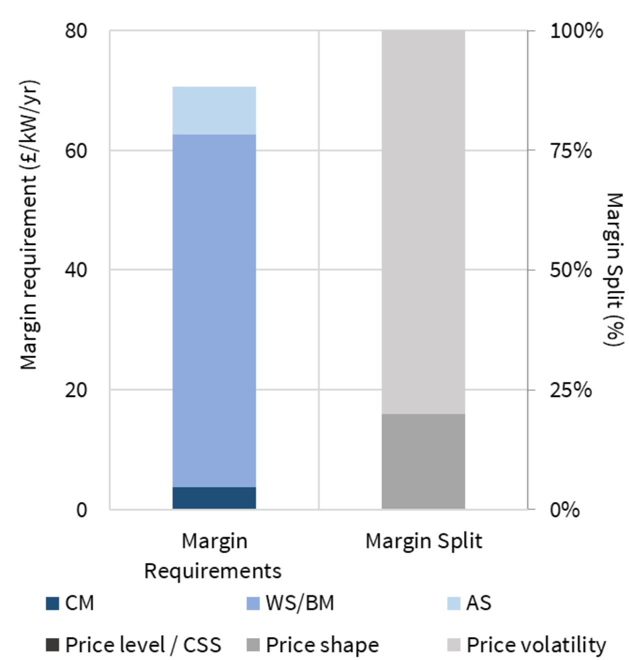


Source: Timera Energy

Value drivers & risks: Batteries

	Value drivers	Risks
Capacity Market	• **Policy:** evolution of policy support in favour of batteries (CM & broader) • **Derating:** derating factors strongly incentivising longer duration storage	• **Cost declines:** uncertainty over scale & pace of technology cost declines • **Degradation:** uncertainty as to battery performance over time
Wholesale & Balancing Mechanism	• **Speed & flex:** e.g. unique response speed & ability to capture low/negative prices • **BM evolution:** value growth focused on rising BM volatility & volumes • **Wind & solar build:** value growth driven by rising RES output swings increasing price shape & volatility	• **Flex overbuild:** timing mismatch between investment & requirement for batteries / engines / DSR • **BM strategy:** achieving scale & sophistication • **Market access:** ability to execute effective trading & optimisation strategy

**Battery margin requirement & split*



Source: Timera Energy

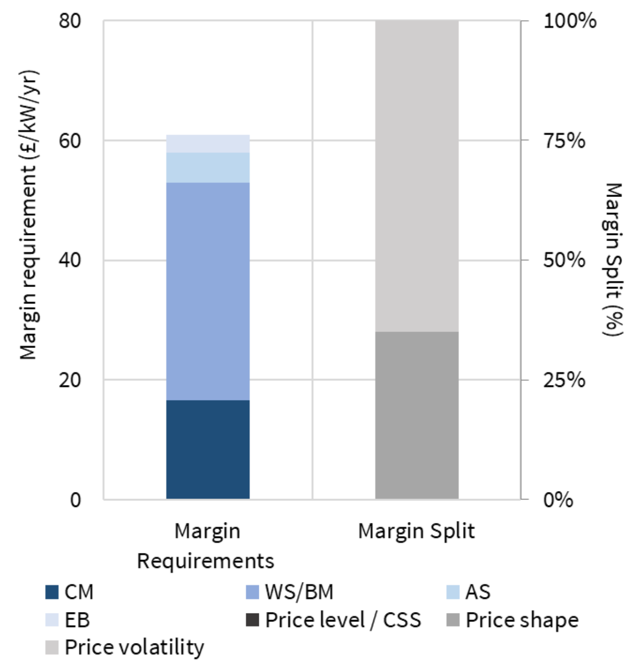
Note: WS = Wholesale Market, BM = Balancing Mechanism, AS = Ancillary Services, EB = Embedded Benefits, CM = Capacity Market, FFR = Firm Frequency Response.

** Required margin in £/kW represents "average annual return you need to believe in to invest" assuming a 17 £/kW CM price. It does not represent Timera's projection of returns.*

Value drivers & risks: Engines

	Value drivers	Risks
Capacity Market	• **15 yr contracts:** ability to underpin returns with stable revenue stream • **Cost:** Relatively low cost of new capacity (~350 £/kW)	• **CCGT life extension:** Lower CM price required for life-extension vs new-build? • **Policy:** Any rule changes in favour of batteries, DSR or interconnectors
Wholesale & Balancing Mechanism	• **Flex & starts:** Very low start costs (vs CCGTs) and high flexibility (e.g. ramps) support competitiveness • **Shape & volatility:** value growth from rising spot & BM shape & volatility • **CCGT interaction:** ability to 'outflex' CCGTs e.g. multiple daily starts; flex up in BM	• **Flex overbuild:** timing mismatch between investment & requirement for batteries / engines / DSR • **Price signals:** slower rise in shape & volatility (e.g. due to RES lags or batteries) • **Market access:** ability to execute effective trading & optimisation strategy

**Engine margin requirement & split*



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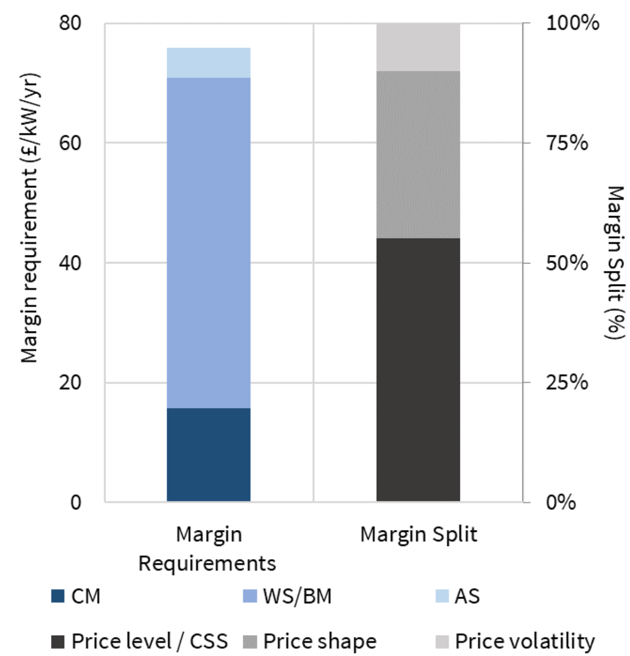
Value drivers & risks: New CCGTs

	Value drivers	Risks
Capacity Market	• **15 yr contracts:** ability to underpin returns with stable revenue stream • **Retirements:** Ability to deliver capacity at scale as coal/nuke fleet closes	• **CCGT life extension:** Lower CM price required for life-extension vs new-build? • **Policy:** Any rule changes in favour of batteries, DSR or interconnectors
Wholesale & Balancing Mechanism	• **Efficiency pick up:** 56%+ (HHV) creates big CSS uplift vs existing CCGTs (+ new plant very flexible) • **Rents:** Rising load factors of peaking assets (e.g. engines, GTs) support CCGT margins • **New entry barriers:** Likely to be a limited window for CCGT new build (3-5GW?)	• **Decarbonisation:** rising tail risk for cashflows 2035+ • **Other CCGT build**: returns cannibalised by others • **Load factor:** Solar-dip & RES reduce load factors • **Flex & starts:** Engines and batteries 'eat CCGT's lunch' from spot & BM volatility

**New CCGT margin requirement & split*



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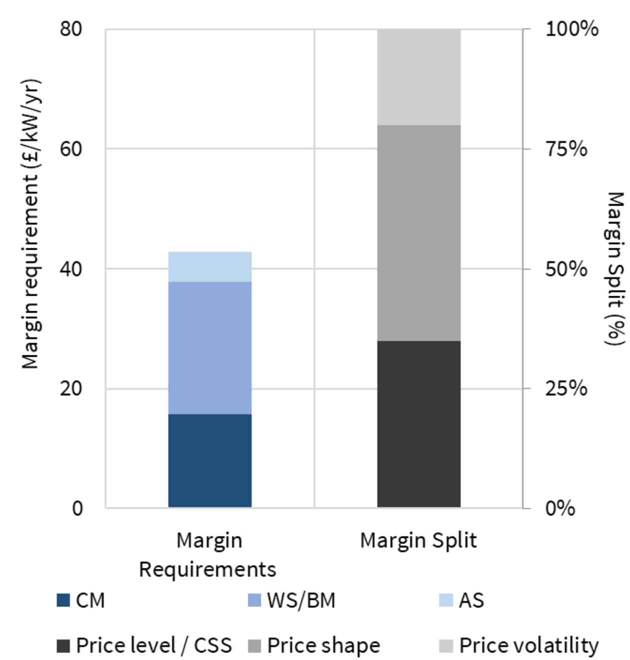
Value drivers & risks: Existing CCGTs

	Value drivers	Risks
Capacity Market	• **Competitiveness:** CCGT life extension cheapest form of incremental capacity • **Optionality:** e.g. ability to refurb asset or bypass steam turbine to run as GT	• **1 yr pricing:** Uncertainty over evolution of capacity price signals • **Cost:** need for major capex spend (e.g. HRSG) can thwart life extension
Wholesale & Balancing Mechanism	• **Peak CSS support:** Dominance of gas plant setting prices supports CSS • **Rents:** Rising load factors of peaking assets (e.g. engines, GTs) support CCGT rents • **BM scale:** CCGTs currently dominate BM value	• **Peak CSS erosion:** threat from build of newer CCGT • **Load factor:** Solar-dip & RES reduce load factors • **Flex & starts:** Engines and batteries 'eat CCGT's lunch' from spot & BM volatility

**Existing CCGT margin requirement & split*



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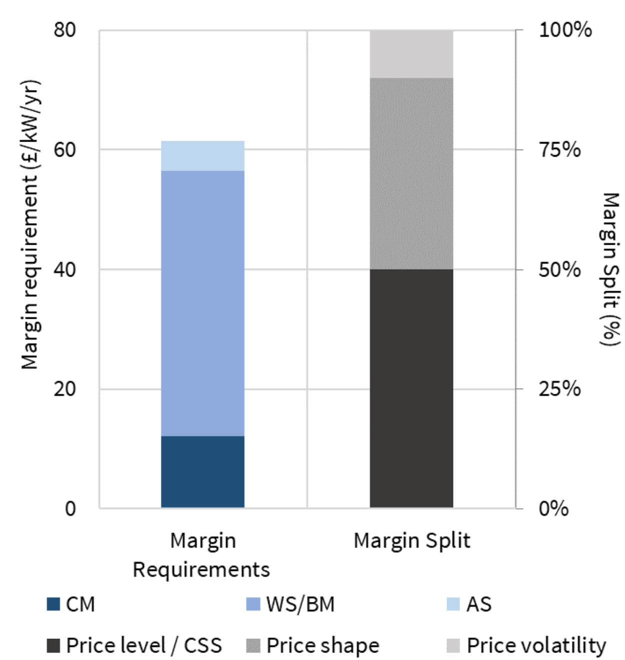
Value drivers & risks: Interconnectors

	Value drivers	Risks
Capacity Market	• **Competitiveness:** Bounded revenue range under the 'cap & floor' regime supports capacity bids • **15 yr pricing:** ability to underpin returns with stable revenue stream	• **Derating:** Interconnector derating based on market price spreads outside of owners control • **Policy:** Strong individual project policy dependence e.g. cap & floor & derating
Wholesale & Balancing Mechanism	• **Intrinsic price spread** between UK & Continent is key driver of revenue e.g. structural differences in capacity mix & load shape • **Market volatility:** Rising volatility increases extrinsic value of interconnectors	• **Price equalisation:** Erosion of intrinsic price spreads due to e.g. removal of UK carbon price floor • **Interconnector overbuild:** overbuild cannibalises market price spreads

**Interconnector margin requirement & split*



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5 key takeaways

Key Point	Explanation
1. Growing flex capacity deficit	• 25 to 30GW of nominal wind & solar capacity may be developed across 2020s (driving big increase in stack fluctuations), but this shrinks to 2-3GW when de-rated for CM. • Coal, CCGT & nuclear retirements mean 25+GW of new flex capacity may be required by 2030 (over & above wind/solar build).
2. Capacity prices set to rise	• Capacity deficit structurally supports capacity prices & investment in flexible assets. • Recent shifts in flex asset returns (e.g. for engines, DSR, interconnectors) are also acting to support capacity prices into Q1-2020 auctions.
3. Price shape & volatility drive value	• Rising price shape & volatility are the 2 structural drivers of increasing flexible asset value. • These are supported by (i) larger wind & solar swings and (ii) steepening supply stack.
4. Growing importance of BM value	• NIV-chasing returns will be cannibalised (decreasing cashout price forecast accuracy). • This will force engines & batteries into the BM, with realistic quantification of BM returns key to building a viable investment case.
5. Stochastic modelling is key	• Multiple (500+) simulations of wind/solar/load profiles and stochastic asset margin distributions are required to develop a robust investment case for flexible assets. • Conventional stack & dispatch modelling does not cut the mustard!

How do we model flex asset value?

Two step stochastic modelling process

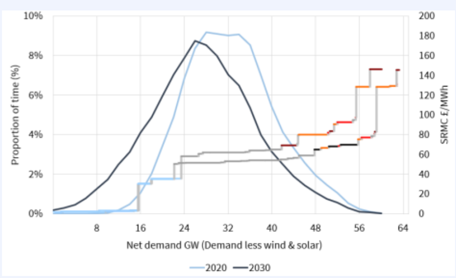
Flexible assets create value by responding to price shape & volatility. Conventional stack & dispatch modelling undervalues this flexibility and creates revenue numbers that are disconnected from what can be achieved in practice.

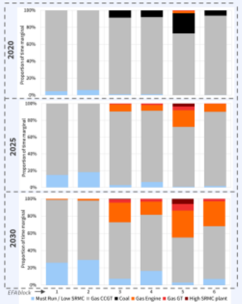
We apply a two step stochastic modelling approach to generate realistic returns:

1. **Market modelling:** we simulate multiple (e.g. 500+) correlated profiles for wind/solar/load via a stochastic stack model.
2. **Margin modelling:** we feed the results of the market model into a separate stochastic dispatch optimisation model that simulates volatile price paths, generates asset margin distributions & projects realistic value capture from asset flex.

1. Market modelling

Supply stack modelling needs to capture the evolving impact of wind/solar and load distributions & associated uncertainty. Robust modelling of swings in wind/solar/load and changing stack shape, drive realistic projections of price level, shape & volatility.

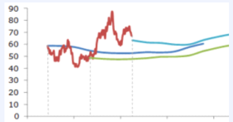




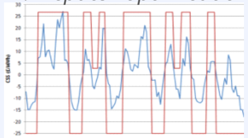
2. Margin modelling

Probabilistic framework required to generate robust projection of asset risk/return and the value of optionality. Stochastic modelling of price dynamics & asset dispatch underpins margin distribution analysis.

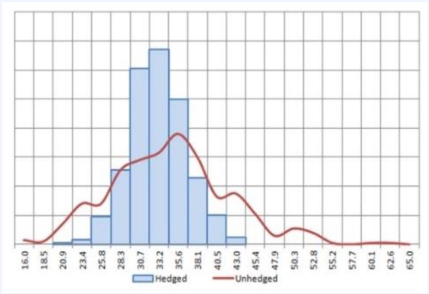
1. Stochastic price simulation



2. Dispatch optimisation



3. Distribution of asset risk/return



Timera Energy offers expertise on value & risk in energy markets

Specialist energy consultancy
We focus on European gas & power and LNG assets

Extensive industry expertise
We all have practical knowledge from industry roles

Pragmatic commercial focus
Our services cover investment, value management & mkt analysis

Strong client base
We work with leading energy companies (producers, utilities, funds)

Leading industry blog
We have 15,000+ regular readers (+ regular publications, conferences)

Our clients include

10 recent UK power credentials

Project	Client	Summary
1. Storage investment	**Fund**	*Buy side commercial advisor for 2GW grid connected UK battery portfolio.*
2. Flex monetisation	**Utility**	*Trading strategy & optimisation of large portfolio of UK gas recips & batteries.*
3. Battery valuation	**Aggregator**	*Value capture & optimisation analysis for operational portfolio of UK batteries.*
4. Flex investment	**Utility**	*Analysis of relative economics of battery vs gas engine investment options.*
5. CCGT acquisition	**Fund**	*Valuation & commercial analysis to support acquisition of UK CCGT portfolio.*
6. CCGT new build	**Fund**	*Valuation, margin projections & hedging strategy for UK new build CCGT project.*
7. Market analysis	**Fund**	*Analysis of impact of battery, engine & DSR roll out on UK power market evolution.*
8. Flex management	**Aggregator**	*Structuring advice on route to market contracts to support engine & battery flex services.*
9. Value management	**Generator**	*Support for development of hedging & risk management strategy for UK gen portfolio.*
10. Margin strategy	**IPP**	*Advice on gas plant margin strategy, including impact of contracting on risk/return.*

Timera Energy power team members

Our team members have extensive senior industry experience and practical commercial knowledge.

David Stokes
20 years energy/commodity market experience
Expert in value/risk management of flexible assets
Industry roles with Origin, Williams, JP Morgan

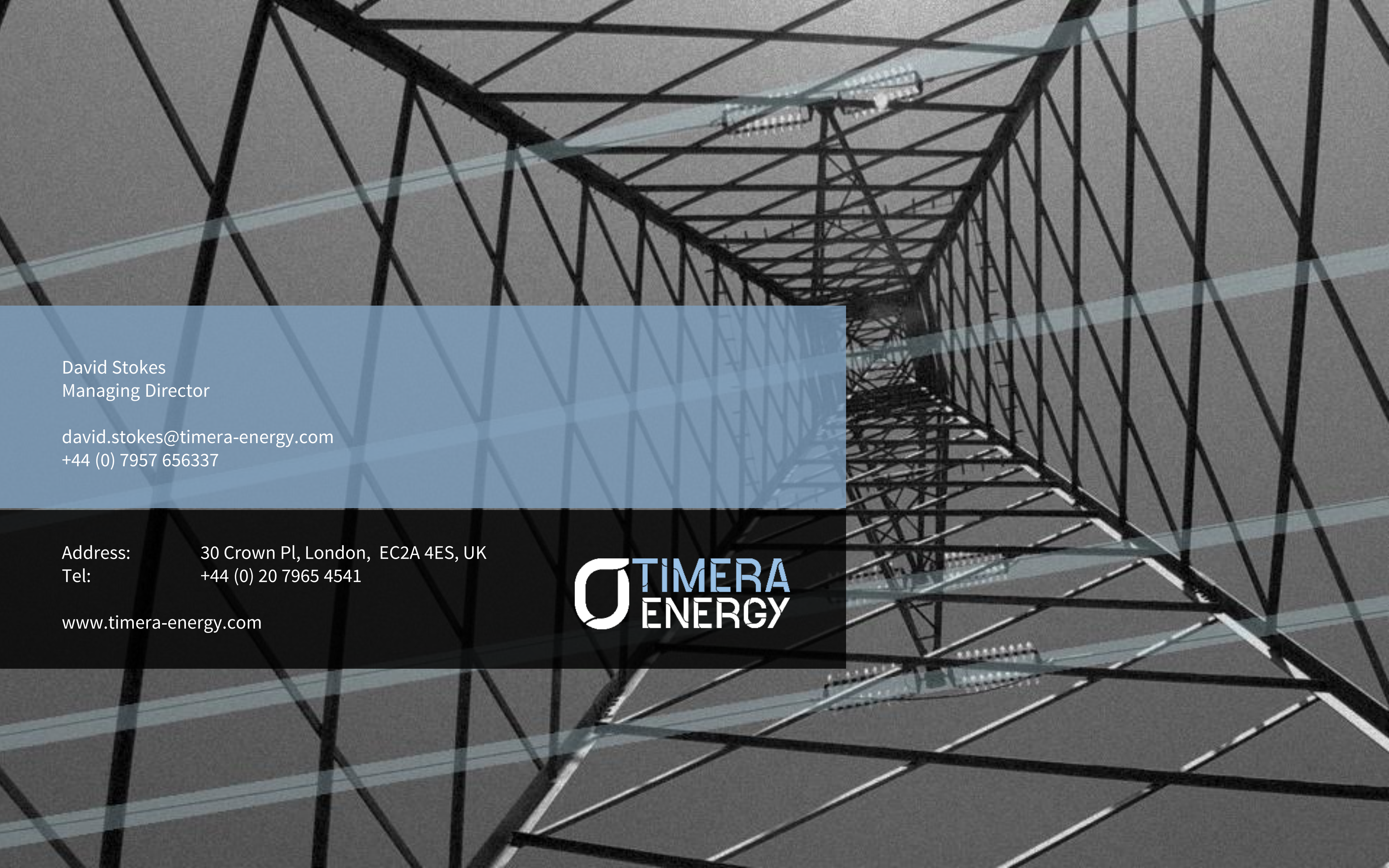
Jessica Gervais
10 years commercial & analytical energy market experience
Strong gas & power market analysis & modelling expertise
Energy trading & commercial analytics industry background

Nick Perry
30+ years industry experience (Amoco, Exxon, Enron)
Expert in commercial & risk management strategy
Board level experience (Enron Europe, Teesside Power)

Olly Spinks
20 years energy industry experience
Expert in commercial and risk analysis
Ran BP's LNG, gas & power commercial analytics function

Steven Coppack
UK & European power, gas & carbon trader at Total
Shift trader dispatching EDF Energy's flex assets
Strong experience of flexible power asset optimisation

Henry Crawford
8 years experience in energy & capital markets
Strong commercial & market analytics experience
Industry trading & analytics background (Nova Energy)



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