



A Review of Current Market Prices in Potential VPP

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Summary

The Key to any assessment for a Virtual Power Plant (VPP) is the prices that one would expect to achieve in the various markets as it forms an important element of VPP revenue generation. There are a number of markets that a potential VPP can sell into or buy from and in the future would include:

- Longer term Storage /Flexibility Markets associated with Transmission (Currently Exists under the UK STOR” arrangements)
- Longer term Storage /Flexibility Markets associated with Distribution (Evolving trial systems set up - see Piclo flex (<https://picloflex.com>))
- Day ahead and real time sales of power between producers (APX and N2EX trading market places – currently available)
- Real time flexibility market at distribution or local level (Future markets evolving and to be developed)
- Frequency response services (e.g. FFR)

Imbalance Price Data on the current UK markets has been obtained and analysed to produce representative prices for these various markets. In terms of future markets a simplified marginal cost based model has been created (Excel VBA based) and has been used to simulate a local flexibility market under varying congestion conditions. In future work it is hoped that a power grid based model will be used to simulate local flexibility price conditions around areas of interest i.e. at use-case locations. This would be more representative of the conditions of the network at particular location.

The Current markets are evolving and regulators including Ofgem are looking to make market access for services like flexibility easier to access. Historically balancing markets have been focussed on providing flexibility or imbalance services via the transmission network. Access to these transmission based markets can still be achieved with the use of the STOR market and via the Piclo Flex auction platform. Flexibility at the distribution market level is still evolving with several pilot markets such as Piclo Flex being made available for this purpose. Real time markets at the distribution level do not currently exist, but it is anticipated that they will.

Routes to market are discussed in a separate document, but this report focusses on prices associated with those markets. In the case of current markets, historical prices are presented and analysed. In the case of potential future markets some views on market price outlook are given where appropriate. In summary average pricing levels for each of the markets discussed are provided in Table 1 Below.

Market	Average Prices	Max Prices	Comments
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UK Balancing Mechanism	In 2021 - £93/MWh ~Previous years before 2019 - Average ~£50	1000-4000 recent years. Prior to 2019 £800/MWh. % times as many spikes over £1500/Mwh in 2021 than 2019-2020	Driven by imbalance volumes that are likely to be bigger in years to come. Also related to underlying cost of marginal generation or DSR - which in the UKI market is related to UK gas prices. This market pays as bid so these figures represent the maximum price that one might expect to get
STOR	£3.1/MW/h	£10/MW/h	Recent tenders Range £0.01-10/MWh (accepted bids) Some bid at £50+
FFR	£5/MW/h	£9/MW/h	Recent tenders range (1-£12/MW/h). Not all cleared
Piclo Flex Utilisation charge	£71-£697/MWh	100-£5833 /MWh	Depends on location and type of assets. From an analysis of Piclo Auction September 2020
Piclo Flex Availability Charge	29-£619/MW/h	39-£4800/MW/h	Depends on location and type of assets. From an analysis of Piclo Auction September 2020
Future local distribution Market Real Time	90-600 £/MWh	286-2500+ £/MWh	Depends on Congestion level of distribution system. Based on simulation examples
N2EX Day ahead market	1st half of 2021 £69/Mwh. Average of year so far £98/Mwh	1st half of 2021 £199/Mwh. Max of year so far £425/Mwh	Based on daily averages - peak could be higher than shown. APX also provides data but requires purchase
APX UK Power IntraDay	Data to be purchased - but data from other markets suggest that average prices could be 0.5 -5% times higher	Data to be purchased - but data from other markets suggest that peak prices could be 2-3 times higher than Day ahead prices	N2EX does not have UK intraday prices
ICE Power futures	Average of £57/MWh over two years	Peak of £264/MWh over last two years (in recent months)	Dec 21 Contract UK Base Electricity Future (Gregorian)

Table 1: Summary of market pricing levels

Introduction/Overview

The routes to market report has identified the potential markets that can be accessed in the UK (Figure 1) either directly or indirectly. The indirect route would use a third party to provide access to the end markets and revenue streams. Typically these parties would charge a fee for these services (including access to the markets) and in return could provide a variety of services ranging from a fixed price contract to a fully value stacked “wrapped ancillary services contract”. Octopus Energy for example provides a dynamic tariff based on the APX market exchange clearing prices at 3pm and can be considered as a surrogate for the imbalance price mechanism¹.

Aggregators or VPP owners² have typically provided services to the market by either offering fixed prices as discussed above or by charging a service fee or margin on the revenues obtained from the balancing market . In the future there are likely to be many types of contract offerings.

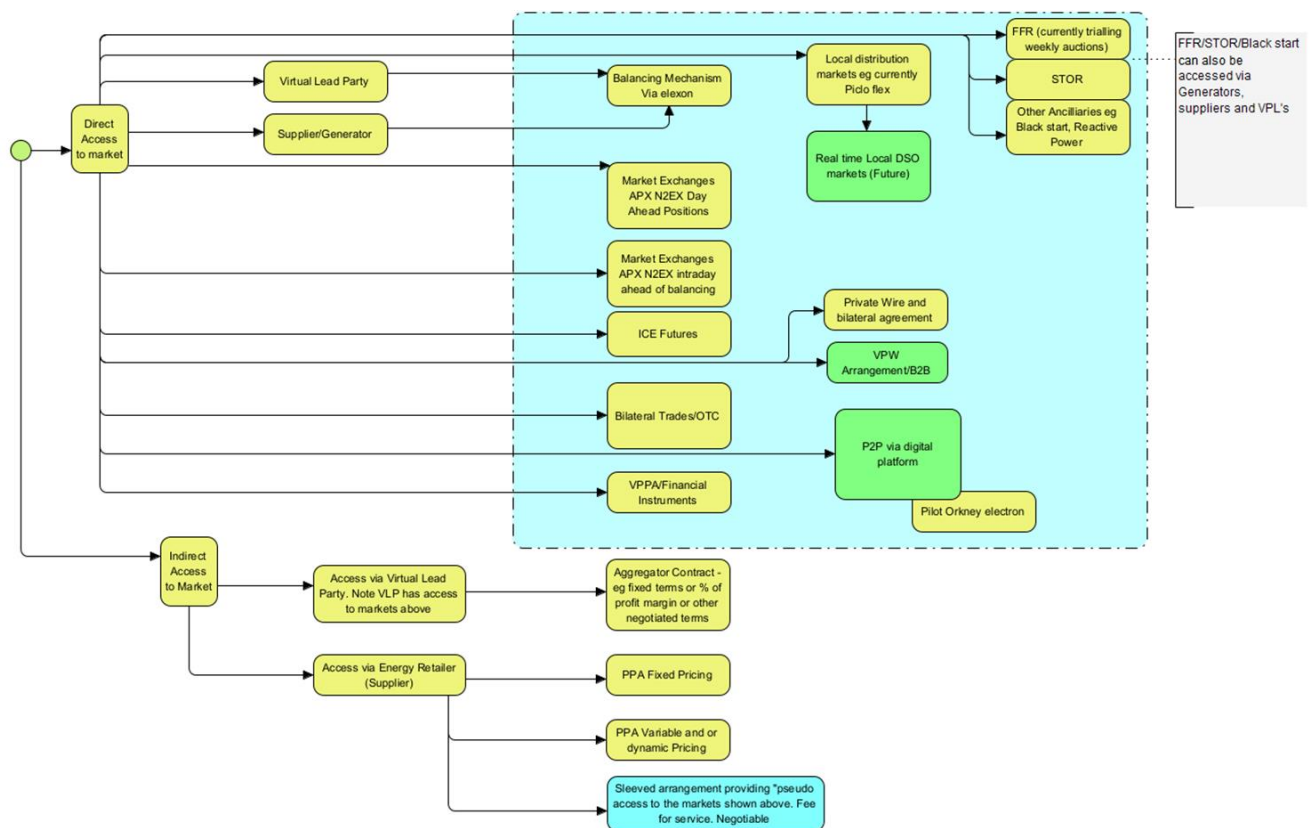


Figure 1:Routes to market

In this short report we provide some of the initial analysis on the current markets (2021).

¹ This is an intraday price in the APX exchange that participants are using before gate closure to adjust their positions before paying the clearing price in the balancing market.

² VPP owners could also be aggregators)

Balancing Mechanism

Balancing mechanism prices can be download from the Elexon portal [1] and have been analysed in the section below. These are imbalance prices associated with providing balancing support at the transmission level. Prices are determined by “clearing” the market using bids and offers. Participants can submit up to ten Bid- Offer Pairs for each Balancing Mechanism Unit. Prices published by Elexon are the clearing prices charged to balancing responsible parties (usually suppliers) for correcting their supply imbalance positions in real time. Providers of the services are given price as bid, so the balancing prices represent a maximum of the price that could be achieved in that market.

The point at which the supply of these bids/offers matches the demand for imbalance volumes determines the clearing price in the market for a particular half hour. In January 2021 “system prices reached or exceeded £1,000/MWh on seven occasions from 6 to 8 January due to cold weather brought on from the ‘Beast from the East 2’”. The largest spike in System Prices in January was seen on 8 January 2021 , when the Price reached £4,000/MWh in Settlement Period 39 and 40 after a price spike earlier in the evening (Settlement Period 35) of £2,750/MWh.

Before January 2021, the highest System Price was £2,242.31/MWh during Settlement Period 37 on 4 March 2020. All of the periods with prices over £1,000/MWh were preceded by an Electricity Margin Notices (EMNs) issued by National Grid ESO which highlighted low margins between available generation and predicted demand [2] . In September prices reached £4,037.80/MWh with an average of £277/MWh (Short prices) seen during the period.

Elexon publishes System Prices within 15 minutes of the end of a Settlement Period on the BMRS and also provides a monthly report (<https://www.elexon.co.uk/data/system-prices-analysis-report/>) that provides volatilities in the market (see example in Figure 2 below)

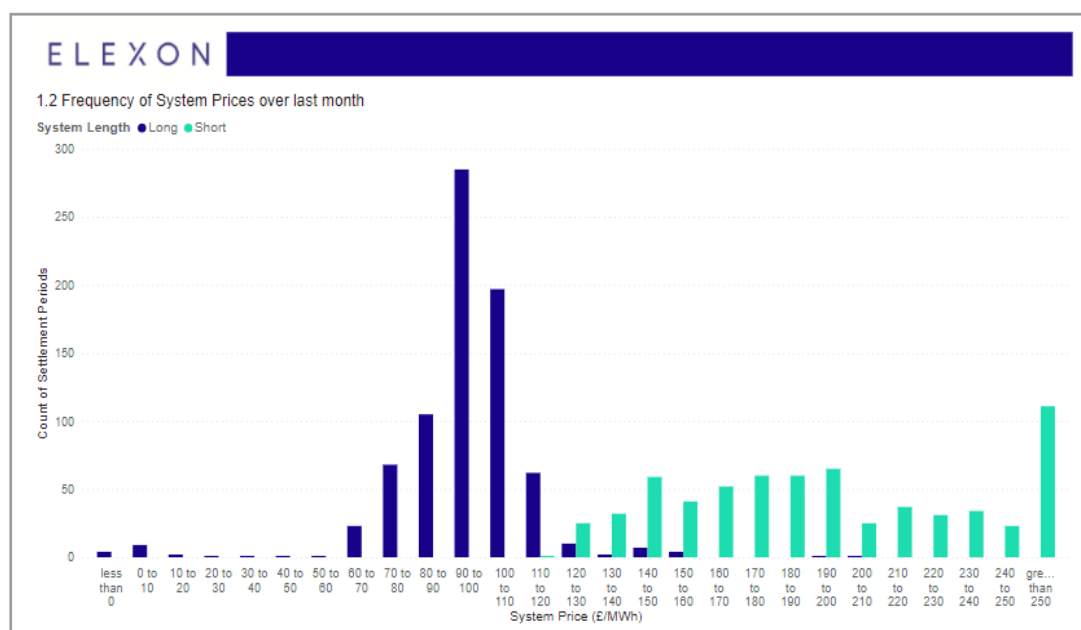


Figure 2: Elexon Price Distribution from monthly BMRS report

Although these values represent the clearing prices in this particular market participants providing balancing flexibility are paid as bid – not paid as cleared. The market can sometimes exhibit negative prices (e.g. -£80/MWh). The prices therefore provide an indication of the best price that would be obtained and bids at values above this would not be cleared.

Historically Elexon published both the system buy and sell prices, but now only publishes the a single price where system price = system buy price = system sell price

Details on how the prices are set in the market are provided in Elexon’s Imbalance Pricing Guidance document (section 3-4) <https://www.elexon.co.uk/documents/training-guidance/bsc-guidance-notes/imbalance-pricing/>

Note: The Imbalance Price calculation aims to distinguish between ‘energy’ and ‘system’ balancing actions. Energy balancing actions are those related to the overall energy imbalance on the system (the ‘Net Imbalance Volume’ NIV). It is these ‘energy’ balancing actions which the Imbalance Price is meant to reflect. System balancing actions relate to non-energy, system management actions (e.g. locational constraints for congestion). These system balancing actions are flagged in the system are dealt with differently from the energy balancing actions. Rather than removing them completely from the price calculation the Elexon system re-prices them based on other energy balancing actions.³ Note STOR balancing is included in this process.

³ This is very confusing and could be simplified or the market could be restructured.

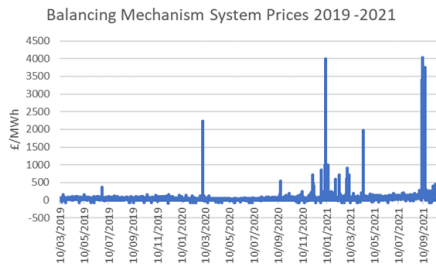
Ranked balancing actions



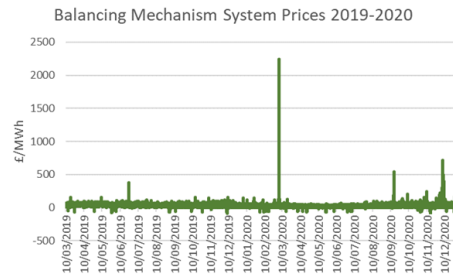
Figure 3: Balancing mechanism bids example

Note transmission losses are allocated by using Transmission Loss Multipliers (TLMs) across 14 zones in this calculation.

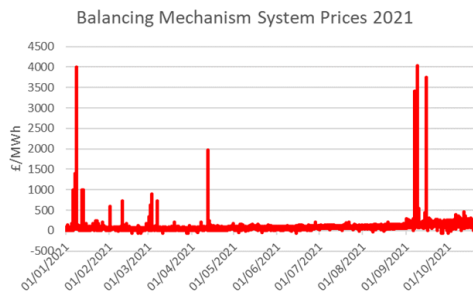
An analysis of the UK Balancing system Prices for 2019 -2021 is shown in Figure 4.



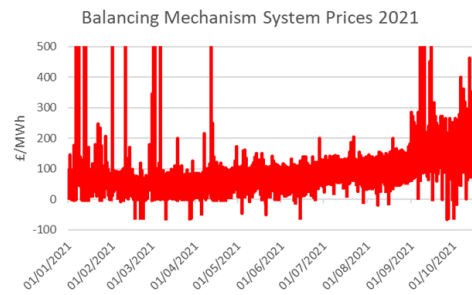
(a) UK Balancing Market 2019 -2021



(b) UK Balancing Market 2019 -2020



(c) UK Balancing Market 2021



(d) UK Balancing Market 2021 Truncated Y Axis

Figure 4: Balancing mechanism prices 2019 -2021

Note Recent prices in 2021 have seen as many as 5 times more spikes over £1500/MWh than in 2020.

Average £/MWh	Average £/MWh	Standard Deviation	Standard Deviation
2019- 2020	2021	2019- 2020	2021
37	93	84%	147%

Piclo Flex (Local distribution flexibility Auctions)

Piclo flex currently (2021) provides auctions yearly in different areas around the UK. DNO/DSO's post competitions asking for flexibility of different type during a number of periods for the following years. Depending on the service either or both an availability revenue is provided (e.g., £/ MW/h) or a commodity/utilisation payment is made on actual delivery (£/MWh). Results of the competition carried out on the Piclo Flex platform can be obtained.. The service that Piclo Flex current provides can be categorised as short to medium term pre-paid congestion services rather than a real time balancing market and is used to negate investment in future system upgrades.

Note Bids do not have to be accepted by the DNO/DSO who themselves are under budget constraints that limits the amount of flexibility that they can buy. Guide prices are also given to flexibility auction participants.

In summary from Auction Results

Although an auction recently closed (Sept 2021), the most recent open source data available on the Piclo Auctions was for September 2020. An analysis of that auction is shown below in Figure 5 - Figure 7: Distribution of utilisation charges in Auction – Piclo Flex. All regions. For the different services, bidders are paid either an availability charge (also sometimes referred to as a capacity charge) and an utilisation (or commodity) charge. Bid lot sizes have ranged from 0.1 MW to around 12 MW (Figure 5), with the majority of them bid below 1 MW.

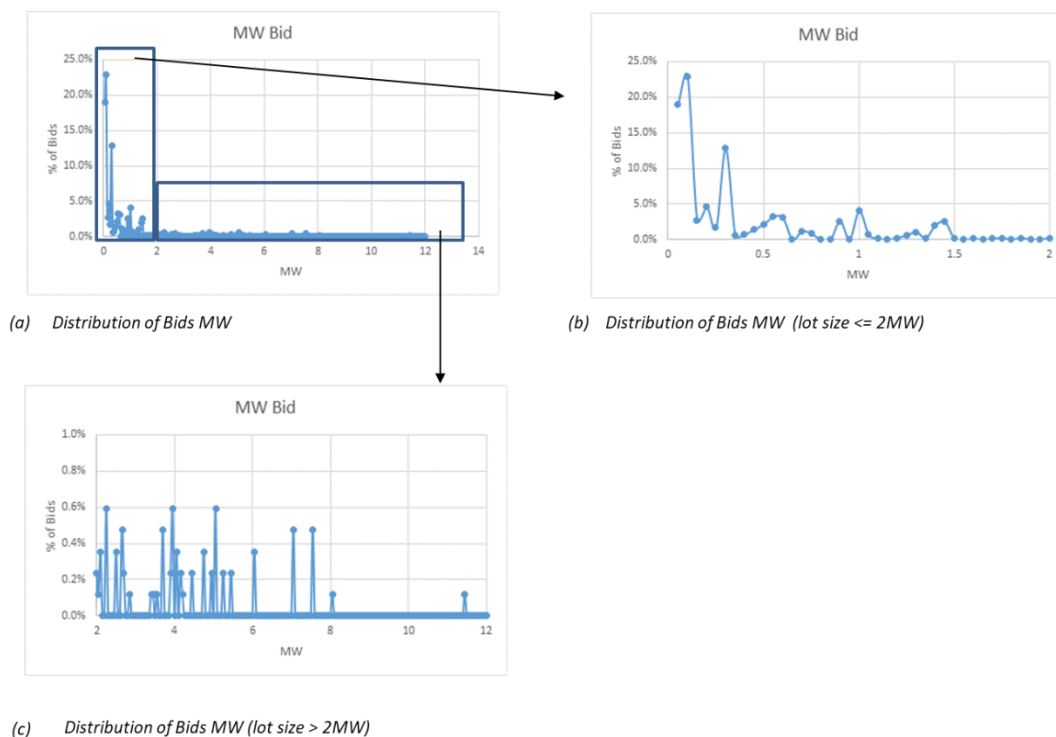


Figure 5: Distribution of MW bid size in auction – Piclo Flex. All regions

Availability Charge Analysis

The analysis of the results indicates that many of the bids for availability were placed in the region of 10 - £100/MW/h although some were bid higher than that (circa £5500/Mw/h) (see Figure 6)

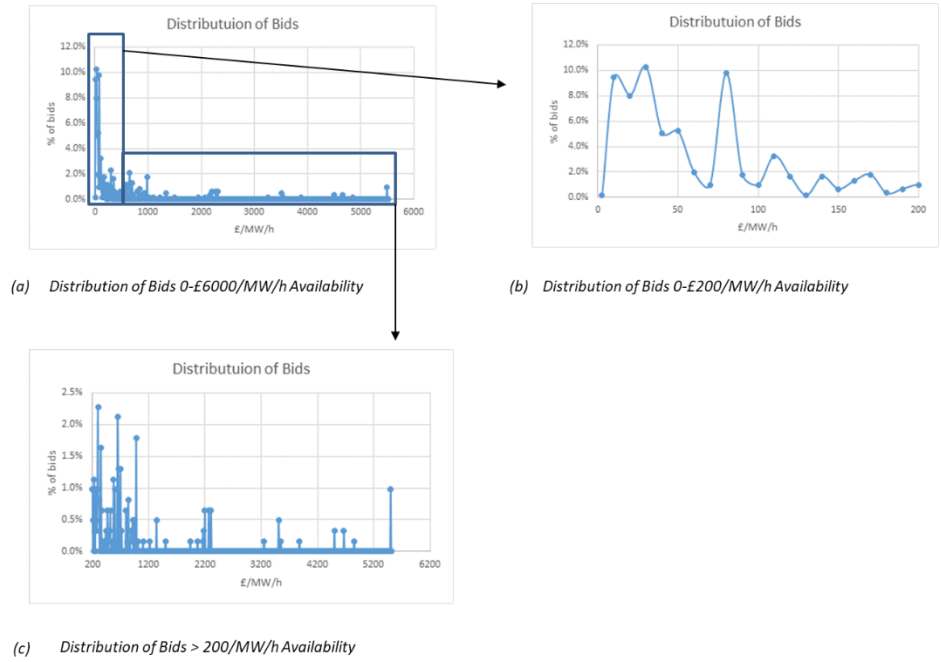


Figure 6: Distribution of availability charges in auction – Piclo Flex. All regions

Utilization Charge Analysis

Utilization bids ranged from £10 - £6000/MWh, with the majority of them placed in the £200-600/MWh.

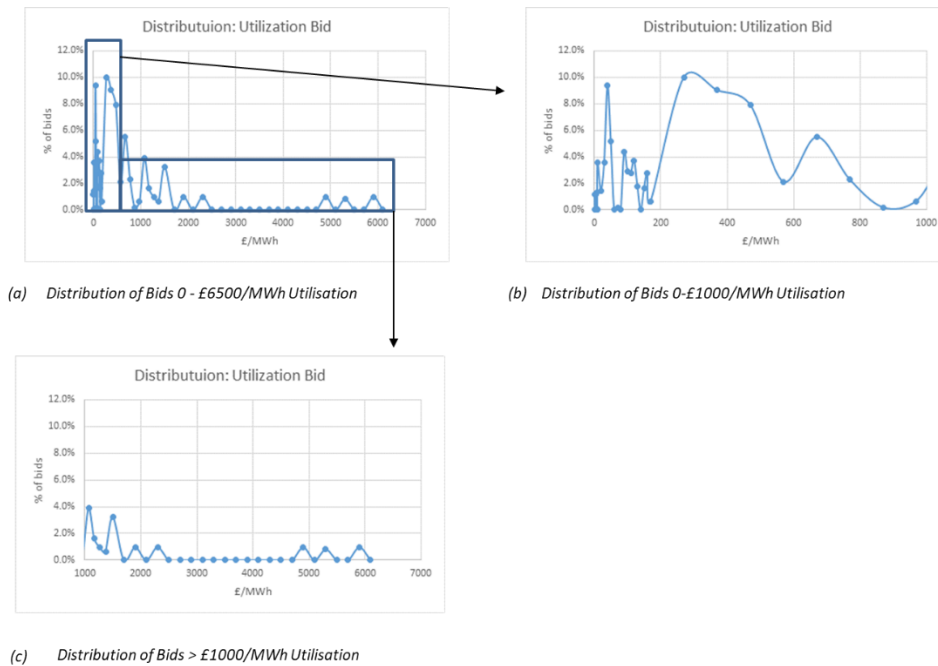


Figure 7: Distribution of utilisation charges in Auction – Piclo Flex. All regions

One would expect that bids would be location dependent and bid price would be correlated with either asset development costs or the level of system constraint.

Even With the limited bid data available it seems there is a correlation of bid levels with asset size exhibiting what one would expect from economy of scale effects. It is difficult however to draw any conclusions about the level of constraint effects, as data is limited to enable that analysis. The majority of the bids in September 2020 were from gas generators or from Vehicle /battery charging facilities (see appendix A2). On average battery/DSR or vehicle charging installations were bidding an average of 0.1 - 0.3/0.4MW at an availability price around £390/MW/h and utilisation prices ranging from £71-670/MWh.

	Average Availability Charge £/MW/h	Average Utilisation charge £/MWh	Average Bid Size MW
battery	619	152	0.1
DSR commercial	196	274	0.1
DSR industrial	148	161	0.3
Vehicle charging/ battery	389 - 396	71 - 670	0.3

Table 2: Bid pricing averages by type of asset

Future Real time Local distribution Flexibility Markets

The independent Piclo Flex market and others like it are auction based. DNO/DSO's associated with the market post details on areas in which they would like to see the availability of flexibility on the distribution network. This is somewhat a one-way process in that the DNO/DSO dictates what flexibility it will require, assesses the technical and financial bid and can decide whether it will accept or reject any offers. This is also somewhat determined by the budget that they have set aside to purchasing said flexibility. It is therefore not a true or value-based market. However, it can be considered a market looking to alleviate congestion, rather than providing real time or very short-term flexibility. University

In system like PJM, price bids/offers essentially in real time⁴ are posted at nodes and provides nodal prices or locational marginal pricing signals, to enable suppliers of flexibility to assess whether there is a need for flexibility assets as well as proving prices for a real time market.

With an appropriate model of the distribution grid such prices can be simulated using an Optimal Power Flow (OPF) model. It will also provide flows in and out of nodes on such a system and highlight constraints. Constrained nodes would be a target for congestion services such as those in the Competitions in Piclo Flex.

Short Term operating Reserve (STOR)

“Reserve is needed for frequency management when there is an imbalance between supply of energy and demand for energy. When the instantaneous supply is not enough to meet the demand, the frequency falls and extra energy is needed very quickly to re-establish this balance. This can be supplied by additional generation or demand reduction. Initially this is provided by frequency response which initiates automatically. Frequency Response services are only maintained for a maximum of 30 minutes. Reserve is then instructed within 2-30 minutes in order to replace the frequency response.” (<https://www.nationalgrideso.com/document/189221/download>)

Until recently the NG ESO Short-Term Operating Reserve (STOR) service operated as a longer term tender process (3 tenders per year). As from April 2021 the NG ESO Short-Term Operating Reserve (STOR) service is now offered as a day-ahead service, where participants can opt in and out of that market on a day ahead basis. This allows them to sell their flexibility to other markets like the wholesale markets e.g. APX exchange.

“During its first month, holding prices for STOR ranged from £0.50/MW/h to £6.50/MW/h, and averaged at £3.00/MW/h. This is higher than during the same period in both 2019 and 2020, according to EnAppSys”. Note some historical long-term firm contracts for STOR still exist till 2025 (for approximately 400MW).

More recent tenders information (including procurement requirements) and prices can be found at <https://www.nationalgrideso.com/industry-information/balancing-services/Reserve-Services/Short-term-operating-reserve/Market-information>. Note units can bid in as non balancing market (BM) units. An analysis of recent bids in the Day Ahead (DA) STOR market is shown below in Figure 8 -

⁴ Bids are made 15 mins or 1 hour before closure as the system has to clear and be ready to dispatch in real time.

Figure 10. Note the biggest volume was bid from balancing market (BM) Open cycle GT's (OCGT) bidding 937 MW.

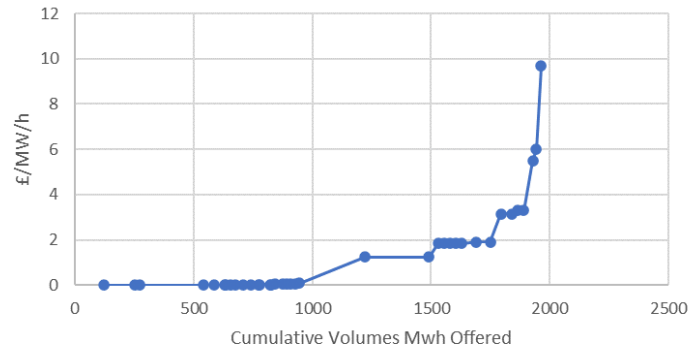


Figure 8: STOR day ahead Auction Prices 27 Oct 2021

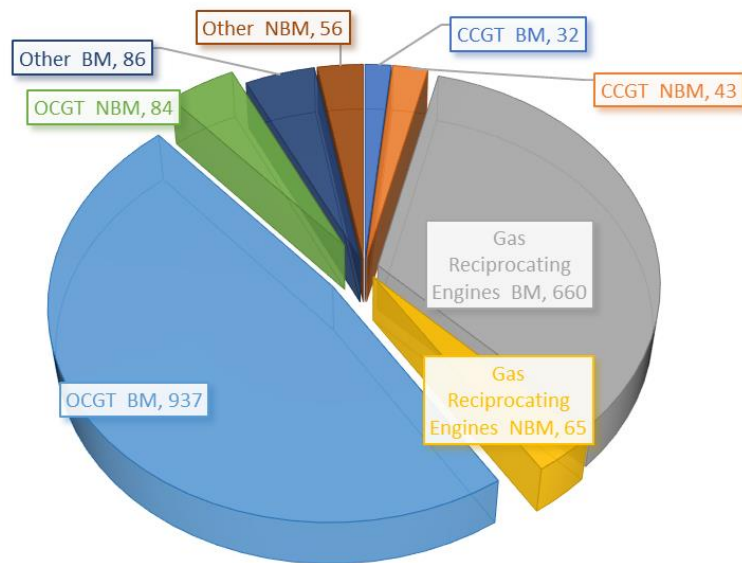


Figure 9: Total volume (MWh) bid in STOR day ahead Auction Prices 27 Oct 2021 by fuel type

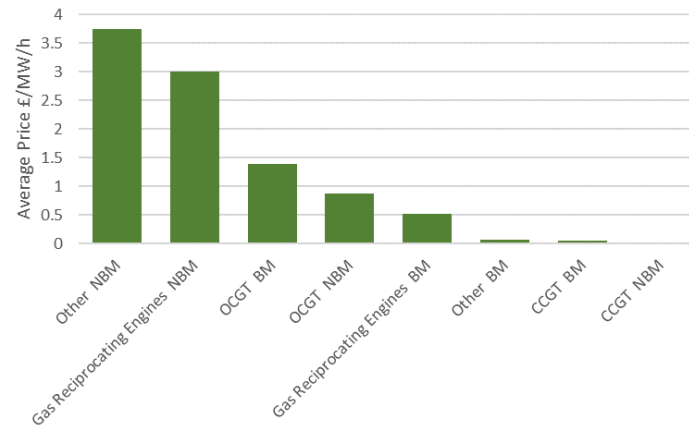


Figure 10: Average STOR day ahead auction Prices 27 Oct 2021 by fuel type

Prices associated with the cleared market since April 2021 are shown in Figure 11.

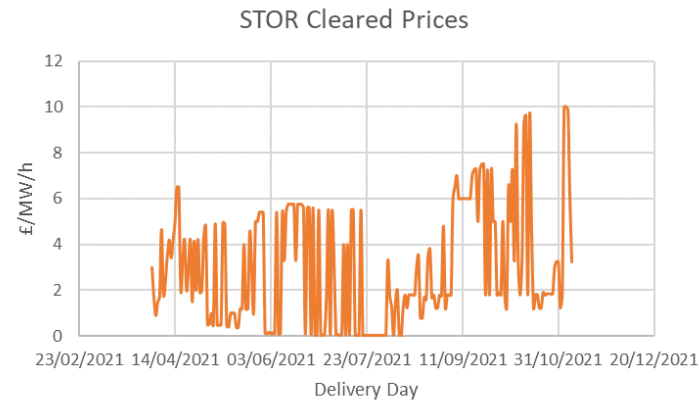


Figure 11: Recent cleared STOR prices (day ahead auction)

Firm frequency response (FFR) Markets

FFR is used to provide both dynamic and non-dynamic response to changes in system frequency. Units must be ready to operate in FFR mode at the start of each FFR window and need to respond rapidly. Electrolysers and Battery storage units are well suited to this task. Revenues from FFR can be value stacked with other services like the balancing mechanism.

Trials on using Wind and solar for FFR has been carried out but are usually unable to respond within the 15 min timeframe required. It is understood that wind and solar may be able to provide useful services to FFR in the future.

A weekly pilot is currently being carried out for FFR services to the transmission system. Data can be downloaded (<https://data.nationalgrideso.com/ancillary-services/phase-2-ffr-auction-results-summary>) and is analysed for week beginning Oct 15 2021 in Figure 12 below. Note this analysis is for all bids, some of these bids would have been rejected.

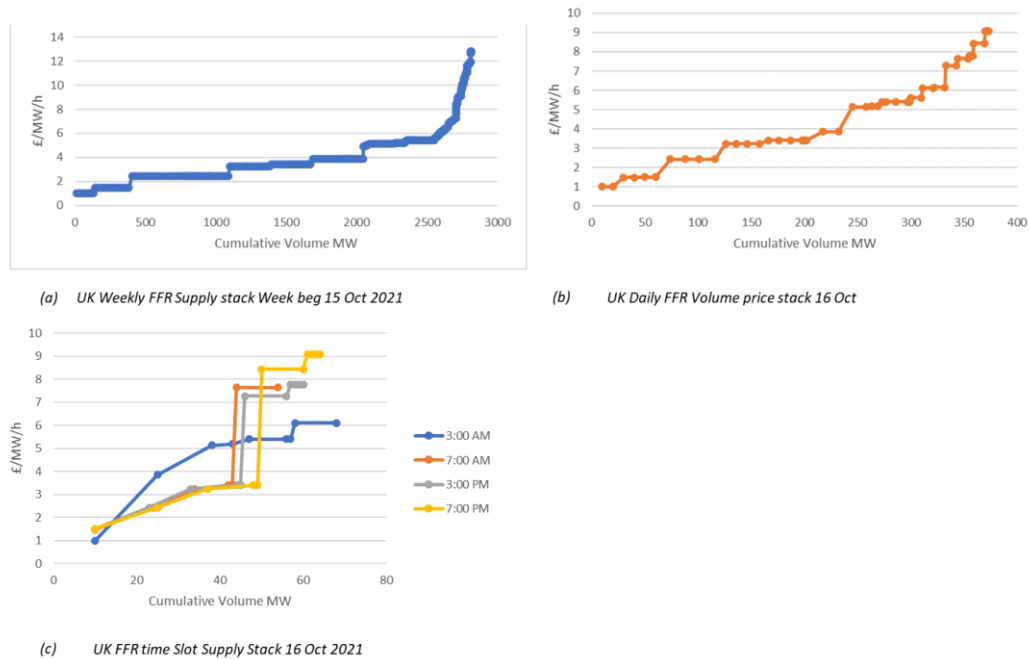


Figure 12: Weekly auction FFR price stack example

Typically FFR bids are in the range £2-12/Mw/h. Daily auction prices for the week ahead are shown in Figure 13 (5 November 2021).

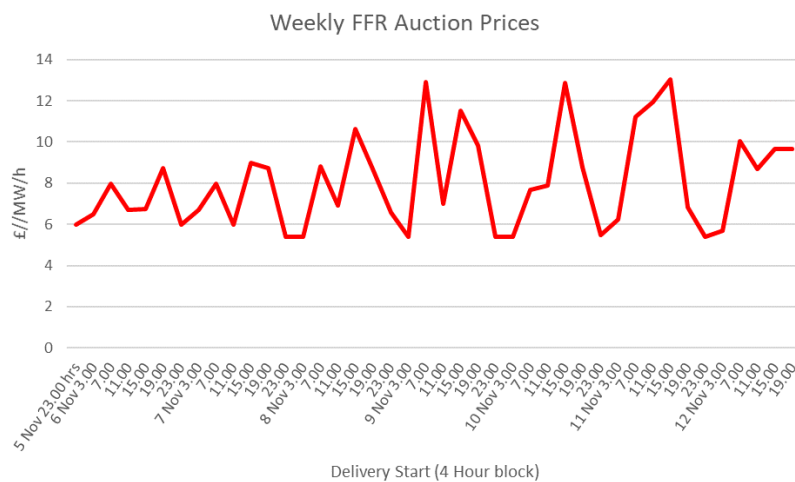


Figure 13: Weekly FFR clearing prices (from 5th Nov 2021)

Exchange Markets (APX, N2EX)

The current UK market is self-dispatching so sellers and buyers of electricity for day ahead and intraday) use market exchanges such as APX and N2EX. Data for these markets can be obtained – some for a fee and will allow analysis of such data. More detailed analysis will be carried out in future work

Note: Octopus offer a dynamic tariff based on the intraday (3pm price) associated with the APX market. Nordpool N2EX prices can be downloaded for free from here but requires formatting for further analysis. Intraday prices would need to be purchased.

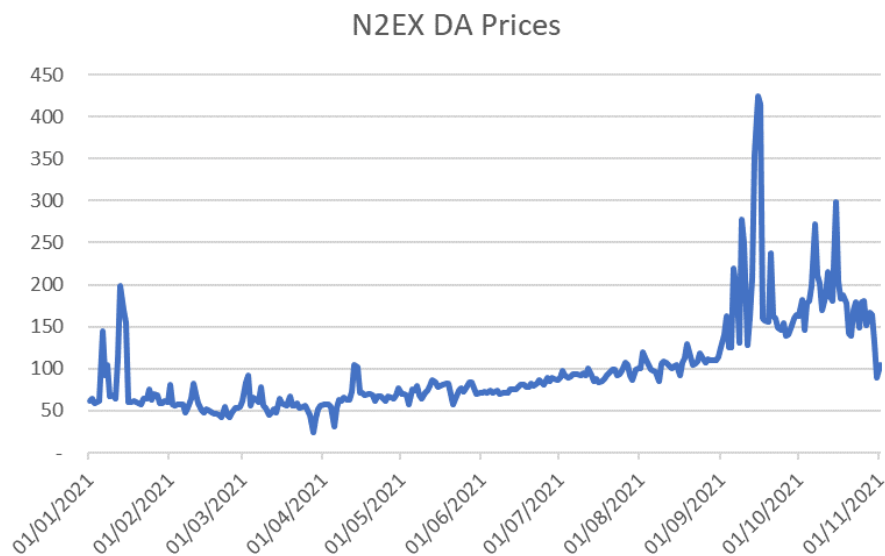


Figure 14: N2EX day ahead prices 2021

Based on these numbers day ahead average prices have a daily volatility of 4.1% equating to an annual volatility of around 80%. Although prices have risen in the last few months (Sept – Oct 2021) daily volatilities in the last few months have only risen to around 5%. Intraday prices are typically higher and one would expect to see higher volatilities in these prices. Intra-day prices can be obtained from Nordpool at €667/month (for trades only - <https://www.nordpoolgroup.com/services/power-market-data-services/intraday-market-data/>).

Note in the case of the APX there are several auctions and prices that are associated with the exchange and are summarised in EpexSpots diagram in [3] shown below.

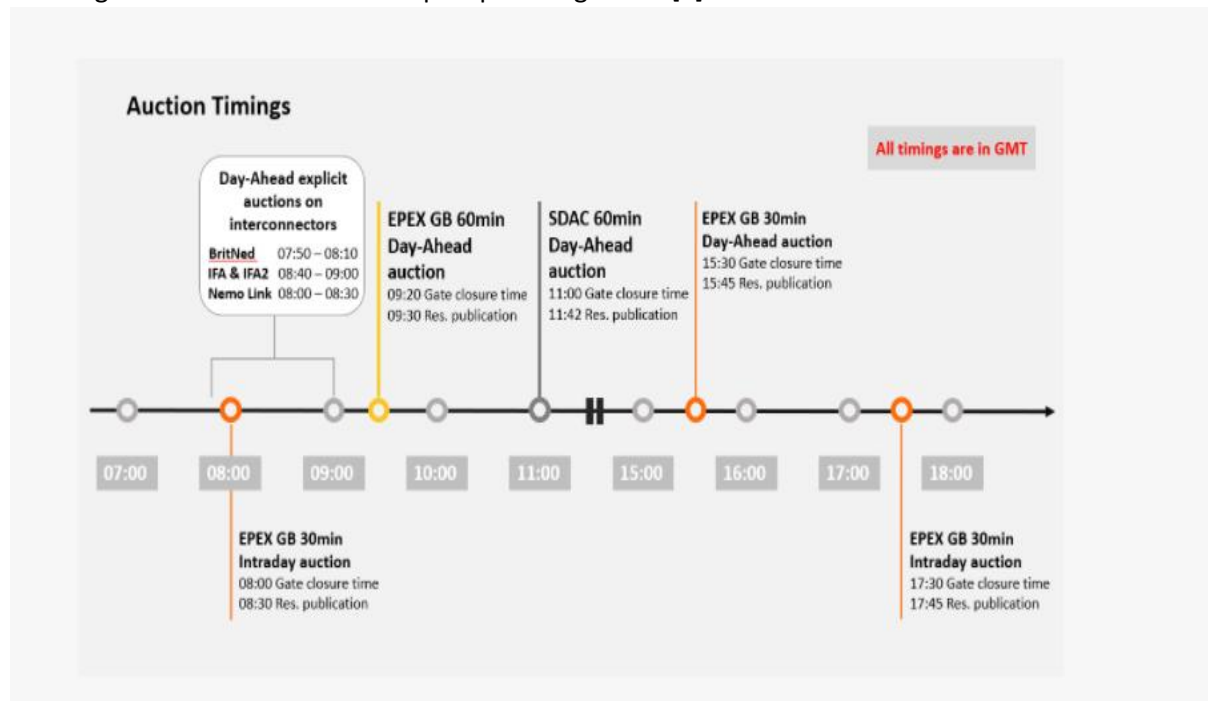


Figure 15: APX UK timings

The most recent auction results can be seen at [4] . Note some markets in Europe have 15 minute bidding. The APX also provides spot or continuous prices. The 08.00 intraday auction is for 30 minute intervals from 12.00 till 24.00 only. Note the first auction for the Day-Ahead(DA) 60 min market occurs at 9.20 am in the morning (e.g. on 7th November for the whole of the next day on the 8th of November). At 15.30 a second DA bid is received for 30 min periods for the whole of the next day (e.g. bid on 7th Nov for 8th November). At 1730 intraday bids are made in 30 minute intervals for the whole of the next day. Finally a further intraday bid is allowed at 08.00 the next day (8th Nov) for this day from 12.00 – 00.00

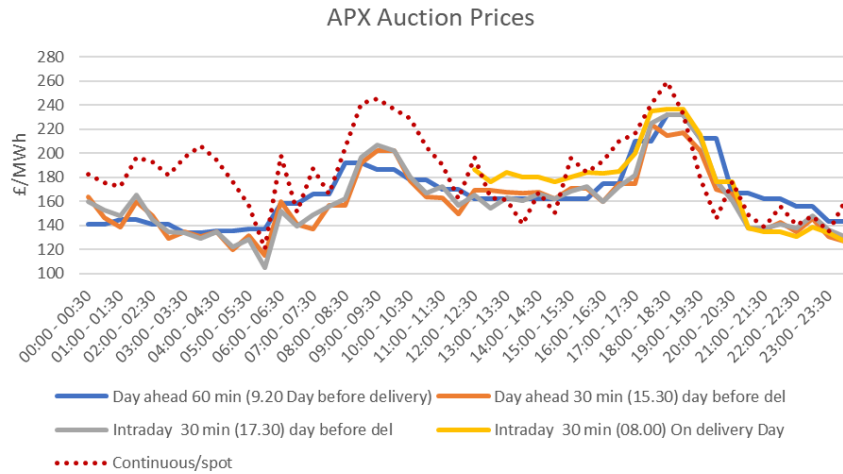


Figure 16: APX prices for 8 Nov 2021 delivery

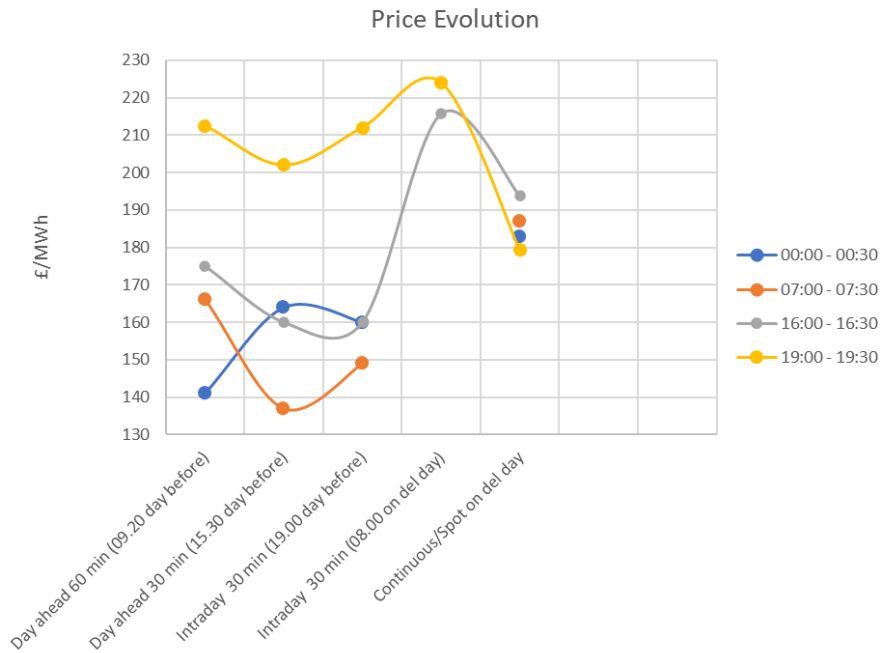


Figure 17: APX price evolution for different delivery periods for 8 Nov 2021 delivery

Futures Markets e.g. ICE

Where hedging is to be used an understanding of the products and their prices would be used to set up a hedging strategy and used to manage the day to day risk of any VPP portfolio. Data can be purchased to allow such an analysis. This is for future work.

Future prices for the Dec 21 contract currently (at Oct 29 2021) stands at ~\$175/MWh with the Dec 22 contract trading at ~£106/MWh.

Three months ago the same contracts were trading at £108 and £74/MWh respectively.

PPA Prices

Future PPA prices depend upon a number of parameters including:

- Views on future projects and their costs including supply and demand for said projects
- Future electricity price views e.g. via ICE. The futures market provides some views 1-5 years out on future market prices
- Market sentiment
- Risk Premium views (Typically the third party provides the supplier buyer with a fixed price and take risk with the floating price)

They provide a “certain” fixed price over a period of time.

Supplier/VPL/Aggregator Deals

Typically linked to markets above and will depend upon the deal negotiated with a supplier. E.g. fixed price or a bundled price depending on markets accessed or individual prices.

Terre

National Grid are a participant of the European 15 minute⁵ balancing market (Terre), which will enable participants in the UK Balancing Mechanism to bid into this market. The market is based at the transmission level although distribution based assets can bid into this market. It has been developed so that services can be harmonised across EU systems. This is a pay as clear market , so participants are likely to earn more here. It is currently not clear how bidding into both markets works and the exact clearing mechanism vis a vis the UK and European market. Seems like excess volumes may be offered to the Terre market to help balancing and volumes fvia interconnectors would be cleared for use in the UK Balancing market.

Currently only two national markets are participating. The UK has delayed its participation to an unknown date. So no price data exists for this market.

⁵ Bid 1 hour ahead for 4 by 15-minute blocks. Aggregators will bid in 15 MW blocks.

References

- [1] Elexon. (2020). *Elexon Portal BMRS*. Available: <https://www.elexonportal.co.uk/article/view/1310?cachebust=sb6m3czktp>
- [2] Elexon, "System Prices spike due to 'Beast from the East 2'," ed, 2021.
- [3] Epexspot. (2021, 1 Nov). *GB Market Post Brexit*. Available: <https://www.epexspot.com/en/gb-market-post-brexit#future-arrangements-what-we-stand-for>
- [4] Epexspot. (2021, 1 Nov). *Auction status*. Available: https://www.epexspot.com/en/market-data?market_area=&trading_date=2021-11-07&delivery_date=2021-11-08&underlying_year=&modality=Auction&sub_modality=DayAhead&product=60&data_mode=map&period=

Appendix

A1 Documents/Useful Links

- Imbalance Pricing guide Elexon :
<https://www.elexon.co.uk/documents/training-guidance/bsc-guidance-notes/imbalance-pricing/>
- APX Prices Day ahead and Intraday – Graphical visualisation EpexSpot
<https://www.epexspot.com/en/market-data>
- Small Market Participants EpexSpot
<https://www.epexspot.com/en/small-market-participants>
- EpexSpot Webshop for data purchase
<https://webshop.eex-group.com/>

A2 Further Analysis of September 2021 Piclo Flex Bids

	Average of Availability (£/MW/h)	Average of Utilisation (£/MWh)	Max of Availability (£/MW/h)	Max of Utilisation (£/MWh)	Average of Service Fee (£/MW)
battery	619	152	3880	300	
Compressed air		697		897	
DSR commercial	196	274	355	614	
DSR industrial	148	161	148	161	
gas	371	228	2198	1000	
Gas reciprocating engines	29	100	39	100	
Mixed asset type	107	400	658	1150	47580
Vehicle charging	396	71	800	100	
Vehicle charging/battery	389	670	4842	5833	47580

Table 3: Price bid summary by asset type

	Sum of Offered Capacity (MW)	Average of Offered Capacity (MW)
battery	2.4	0.1
compressed air	33.0	6.6
DSR commercial	1.8	0.1
DSR industrial	0.9	0.3
gas	128.3	2.5
gas reciprocating engines	11.4	3.8
mixed	67.5	1.1
unknown	3.9	1.0
vehicle charging	1.0	0.1
vehicle charging/battery	193.4	0.4

Table 4: Piclo Flex volumes bid by asset type