Analysing the potential economic value of energy storage

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Reporting on work with Monica Giulietti, Luigi Grossi and Elisa Trujillo

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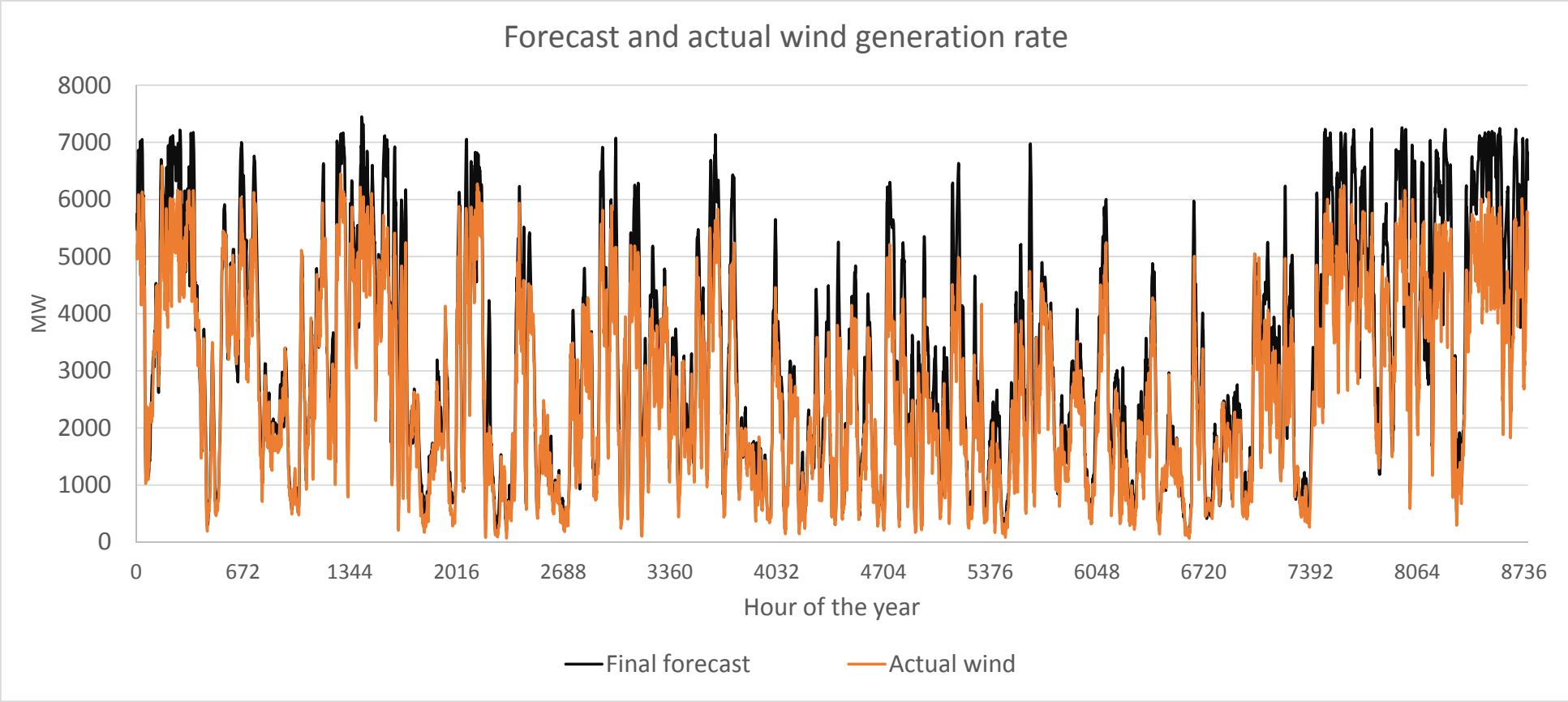
Background

- GB context- an “electrical island” with limited interconnection with other countries
- Significant and continuing growth in non-biddable and volatile renewables
- Rapidly declining baseload plants
- Government involvement limited; *commercial* considerations will be foremost
- Questions:
  - Is there a clear requirement for storage?
  - What will be the focus of commercially-provided storage?
  - Will this tackle the issues of intermittency and volatility?
- Assumption: Large scale storage will essentially operate on basis of arbitrage

Plan

- The problem with wind generation in the British context
- Limited alternatives to storage
- Arbitrage as a focus for commercial storage; the “first arbitrageur” concept, basing storage (roughly) on compressed air plant
- Methodology for profitability simulations
- Generating forecasts of profitability
- Further issues: Predicting wind generation
- Conclusions

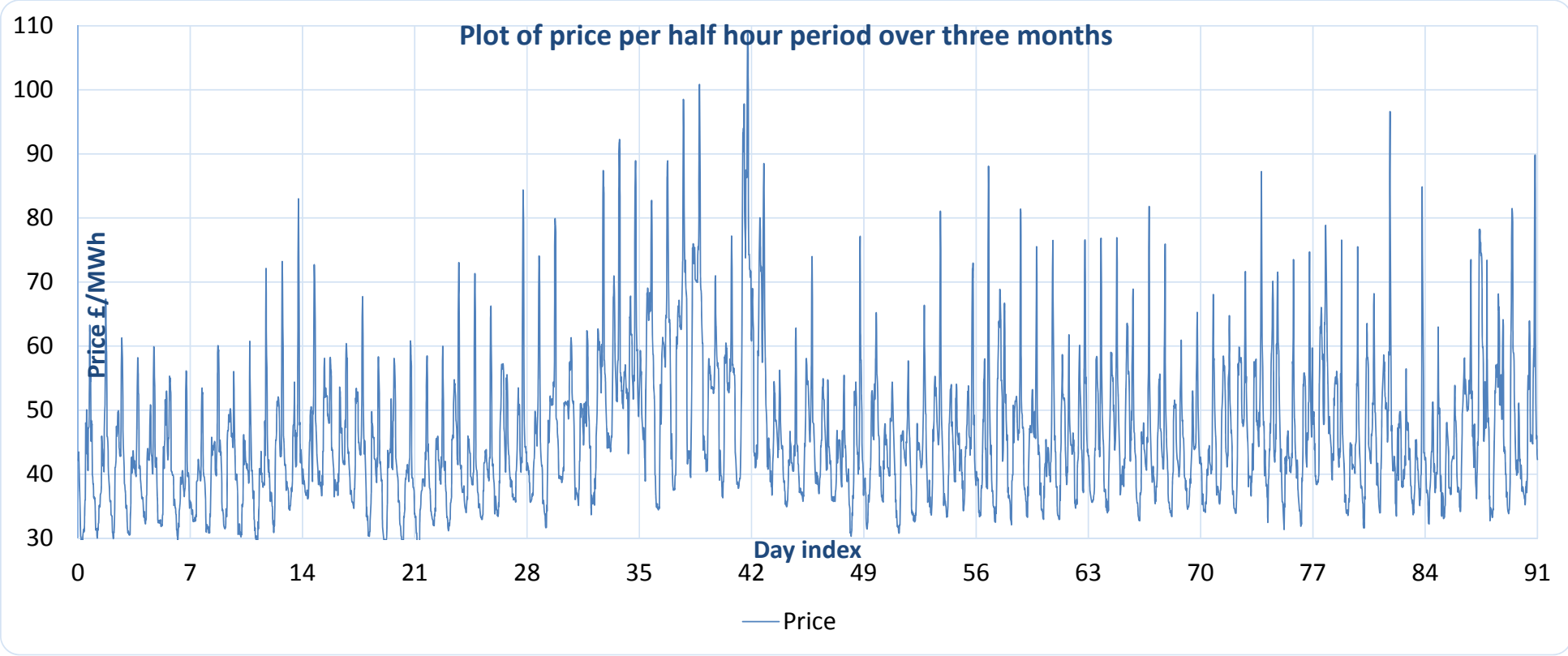
The characteristics of wind generation (Year 2015)



Limited alternatives to storage

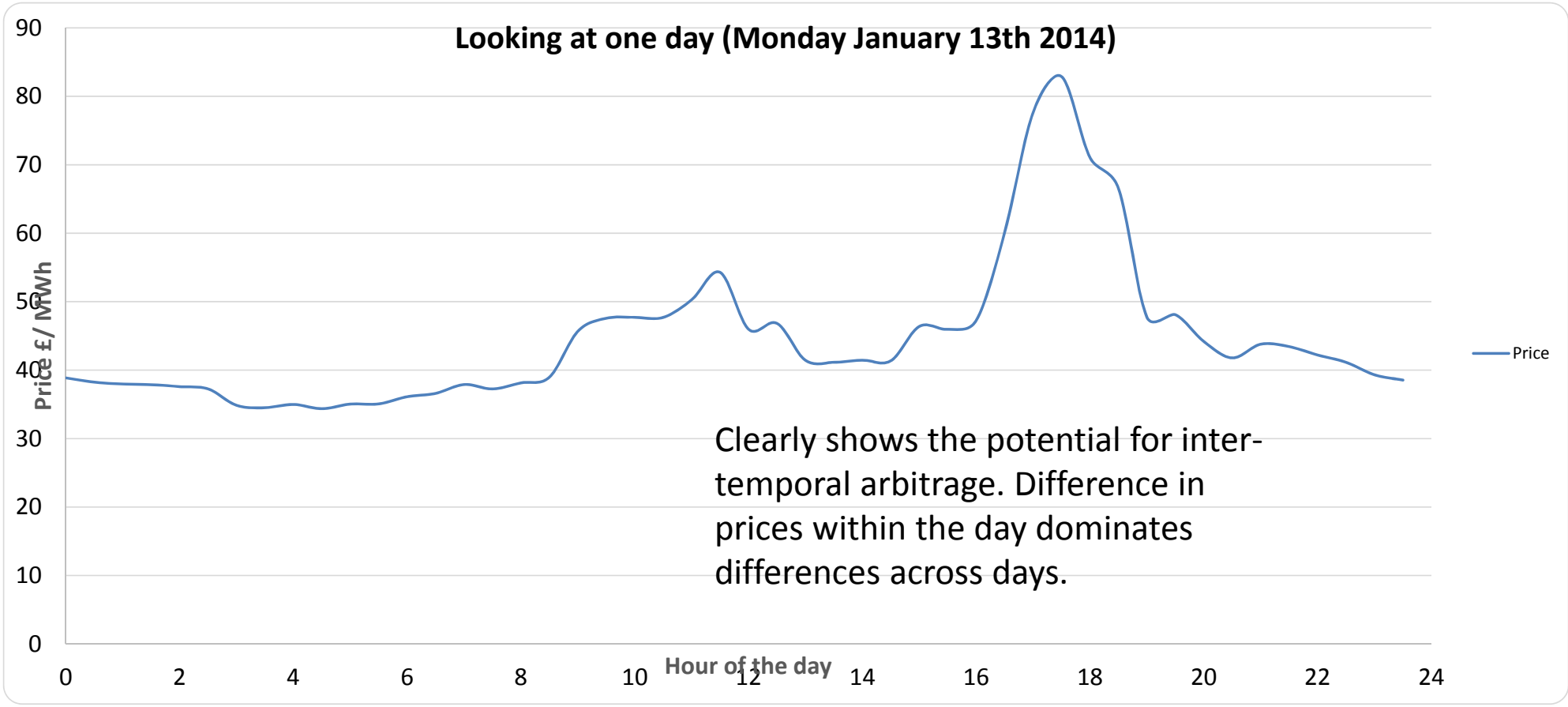
- Interconnectors: Currently, when in full operation, total capacity is around 6GW, including Irish interconnectors. Barely enough to cover even current wind fluctuations even assuming maximum flows to GB (which is unlikely)
- Demand management has limited potential in the British domestic context; few people have electric space heating or hot water cylinders. Use of electric cars for this purpose unproven
- What will commercial storage focus upon? Examine arbitrage, due to big price fluctuations.

APX half-hourly mid-price, first three months of 2014



Looking over a year, there is no big difference across seasons

An example of a fairly typical daily price pattern



Methodology for profitability simulations (1)

- The model assumes there are two important factors in operating a store. First, there is a cost in inputting and outputting MWh, given the store's efficiency, $\theta < 1$,

  $[(1+\theta).x + y]$ per MWh of electricity produced (e.g. cost of running pumps)
- Second, there is the benefit, being the difference in price between that paid for the inputs and received for the outputs: $[p_y - (1+\theta).p_x]$ per unit
- We assume that the store charges or discharges at full rate, taking an equivalent amount of time for each, hence it has an input pumping capability of $(1+\theta).\alpha$ and an export pumping capacity of α MW. It has size $A \equiv \tau.\alpha.(1+\theta)$
- The plant inputs for τ periods and exports for τ periods per day (for simplicity). The remainder of the analysis considers the optimal value for $\tau, \tau*$ by examining 1 period, 2 periods, etc. and calculating that value which maximises the difference between returns and costs
- $A \cdot \left\{ \frac{1}{\tau^*} \cdot \sum_{t=1}^{\tau^*} \left[p_{yt}^d - (1+\theta) \cdot p_{xt}^d \right] - \left[(1+\theta) \cdot x + y \right] \right\} \equiv A.B$
- The store doesn't affect prices, by assumption

Methodology for profitability simulations (2)

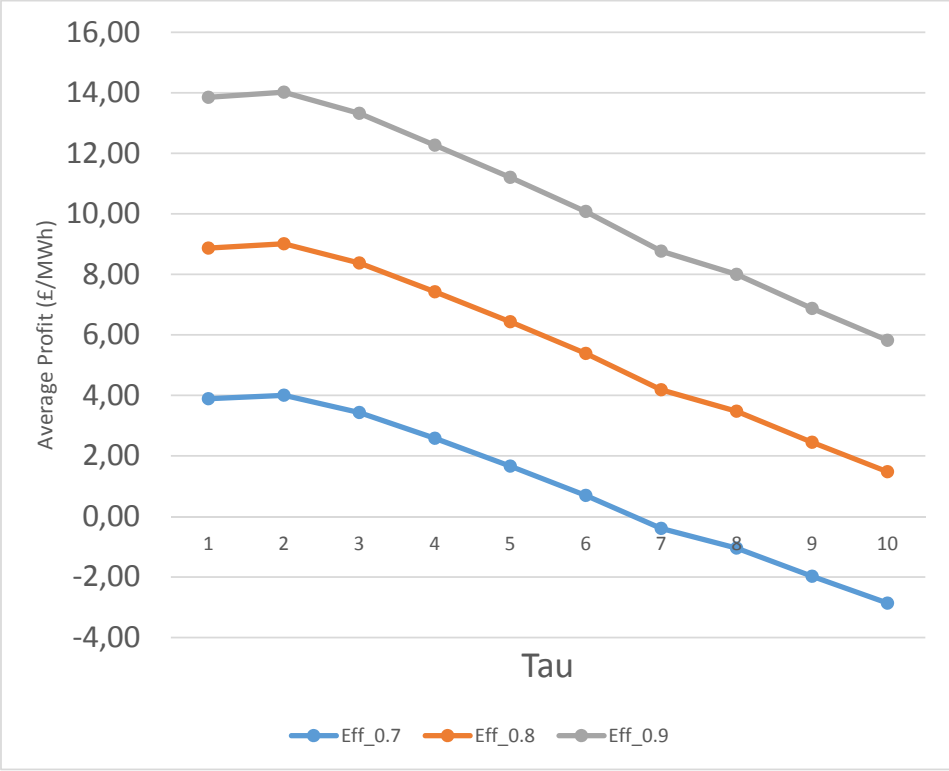
- Values assumed for *x* and *y*, based on compressed air plant
- Once optimal tau found, using the calendar years 2011 to 2014 inc:
- Two approaches to simulating the effects on 2015

1. Apply the strategy devised for 2011- 2014 on 2015 prices
2. Using a rolling window, move forward day at a time, using a SETAR(7,1) model [Self Exciting Threshold Auto Regressive (SETAR) with 1-period lag and autoregressive order 7 (days)]

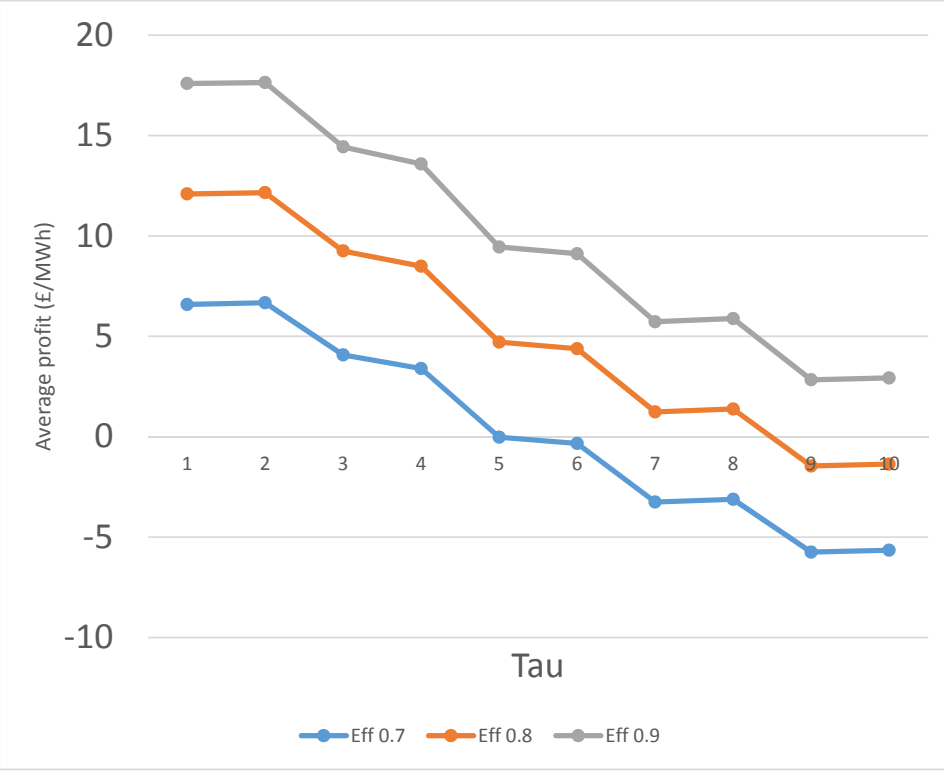
- Optimal tau is calculated using efficiency rates of 0.7, 0.8, 0.9 (only the first being appropriate for CAES storage)

Results on Tau

Using 2011 to 2014 as prediction



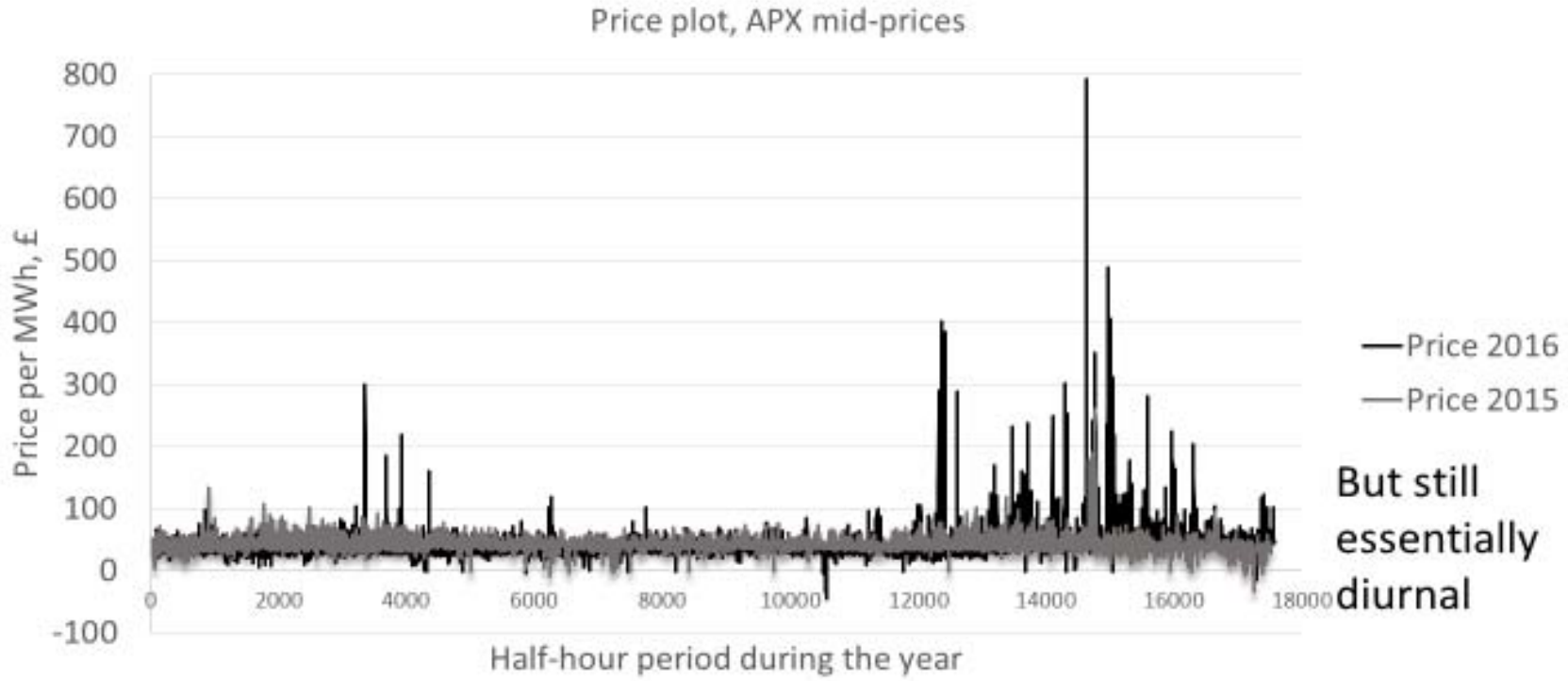
Using SETAR approach



Implications

- Average private profits can be positive for a suitably efficient store, assuming the store has been constructed
- Construction cost values difficult to obtain
- Optimal store on either method is small, in order to gain the benefits of the maximum price difference between the highest and lowest prices over the day; choice between very small store (2-period), maximising average profit per period, or somewhat larger (6-period), where the next, marginal period contributes nothing
- Hence, although the compressed air storage technology is capable of long-period storage, in practice the time-scales imply that batteries are likely to be commercially more viable
- Compressed air would not in practice smooth over longer periods if operated commercially, given current price patterns
- Not claiming that the strategy is optimal, strongly suggests small store size.

What might change?
(1) Price differences may increase, leading to greater benefits



But still essentially diurnal

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(2) Prices may become more sensitive to wind generation predictions

Are they already sensitive to predictions?

IV regression of forward price on predicted load and forecast wind, 2015

	Linear		Log log	
	Coefficient	Standard error	Coefficient	Standard error
Predicted Load	$7.73*10^{-4}$	$2.07*10^{-5}$	0.610	0.0164
Forecast wind	$(-)1.70*10^{-3}$	$5.89*10^{-5}$	(-)0.106	0.004
R squared	0.278		0.287	
Obervations	8760		8760	
Instruments for Load are: day, time, squares and cubes of these, interactions between these. The R squared for the first stage is 0.683.				

Yes, but not very sensitive; not enough to make a difference

Wind predictions are not good beyond a day or two anyway

Conclusions

- Storage has the potential to smooth the very erratic generation from wind, and has the capability for storage over days
- However, commercial storage is likely to be focused on short-term benefits, largely diurnal differences at the highest and lowest price points, not longer-term events
- The capacity market provides a potential additional revenue source, but currently is not configured such that it attracts storage, in part because portfolio bids are not allowed
- The need for a range of solutions, including storage, is likely to increase over time as more wind generation is developed