Analysing the potential economic value of energy storage in Britain

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Context

- Power markets throughout the world are changing:
  - Increased renewables, across 144 countries
  - Declining nuclear
  - Phase-out of coal?
  - Pressure to use less gas?
- This has significant implications:
- Coal and gas are both biddable and storable (97/17 “average” days storage in Britain)
- Wind and solar are neither biddable nor (at least currently) stored, nor do they match load well
- So what are the implications?
- These differ by country; we investigate GB
- But some other countries will be in a similar position

Overview

- Wind (for example) is variable, so increased wind generation will lead to increased variability
- Traditional solution to this is conventional generator back-up
- Can storage provide an alternative, “greener” solution?
  – How will the analysis differ in this case?
- Is *commercial* storage likely to come forward to fill this gap?
  – Are there issues that still need solving?
- Note: Different countries are in different strategic positions.
- But the general message is that “prices tell us something” about the possibilities for commercial operation.

Plan

- Questions to be analysed
- Some data on the problem and on prices
- The scope for commercial storage given this
- Potential developments in future and their impact on the role of storage
- Alternative approaches to storage that do not involve earnings from arbitrage (alone)

Questions and Conclusions

In the context of a significant move to unbiddable renewables

1. Is there a requirement for storage?
2. What will be the focus of commercially-provided storage?
3. Is this focus sensible?

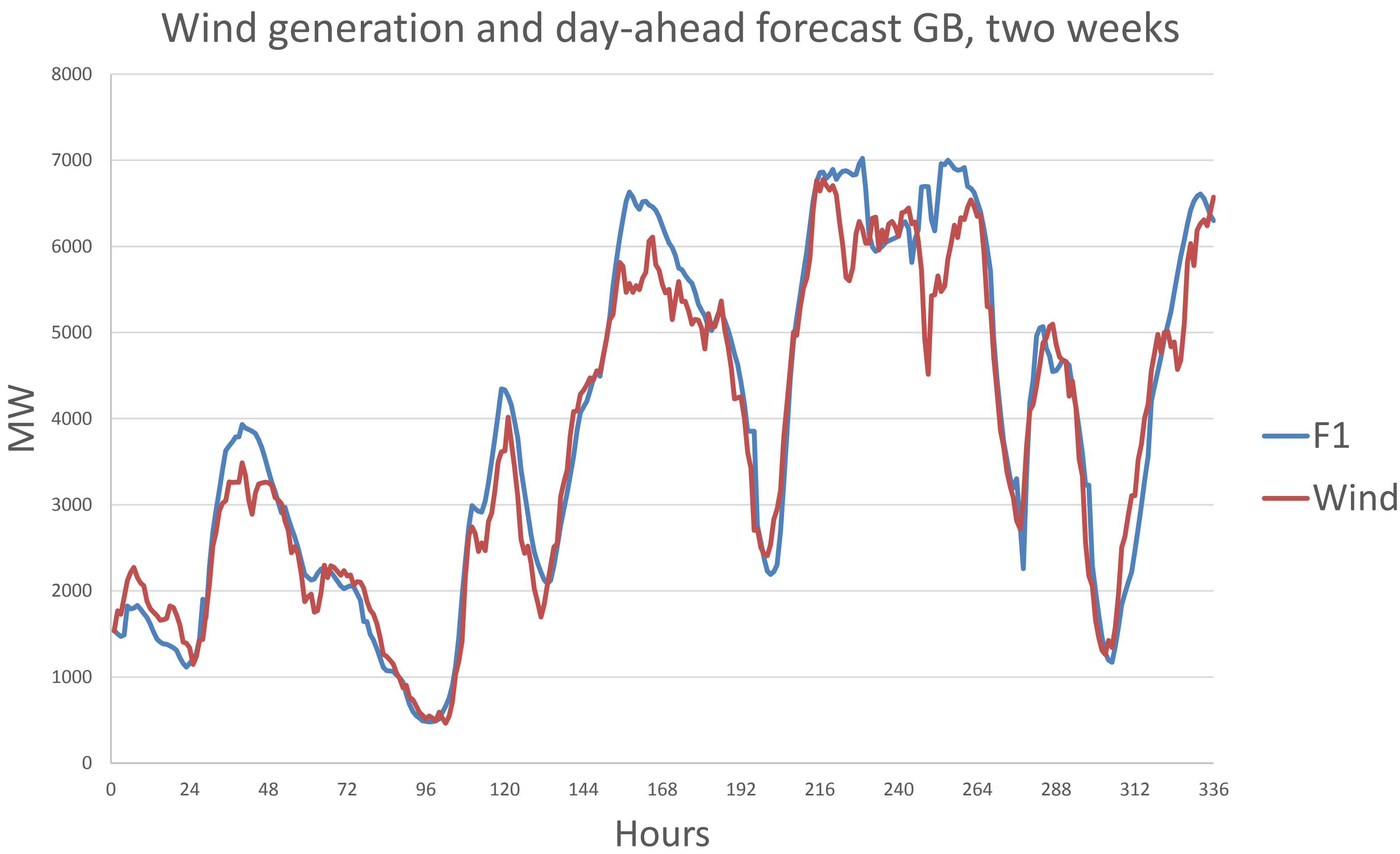
Answers:

1. Yes (for GB) and it is considerable, if replacing peak gen
2. Diurnal arbitrage will be the potential earner
3. But, this gives rise to its own problems: there is a role for storage but not necessarily the one that arises through arbitrage.

The nature of the problem

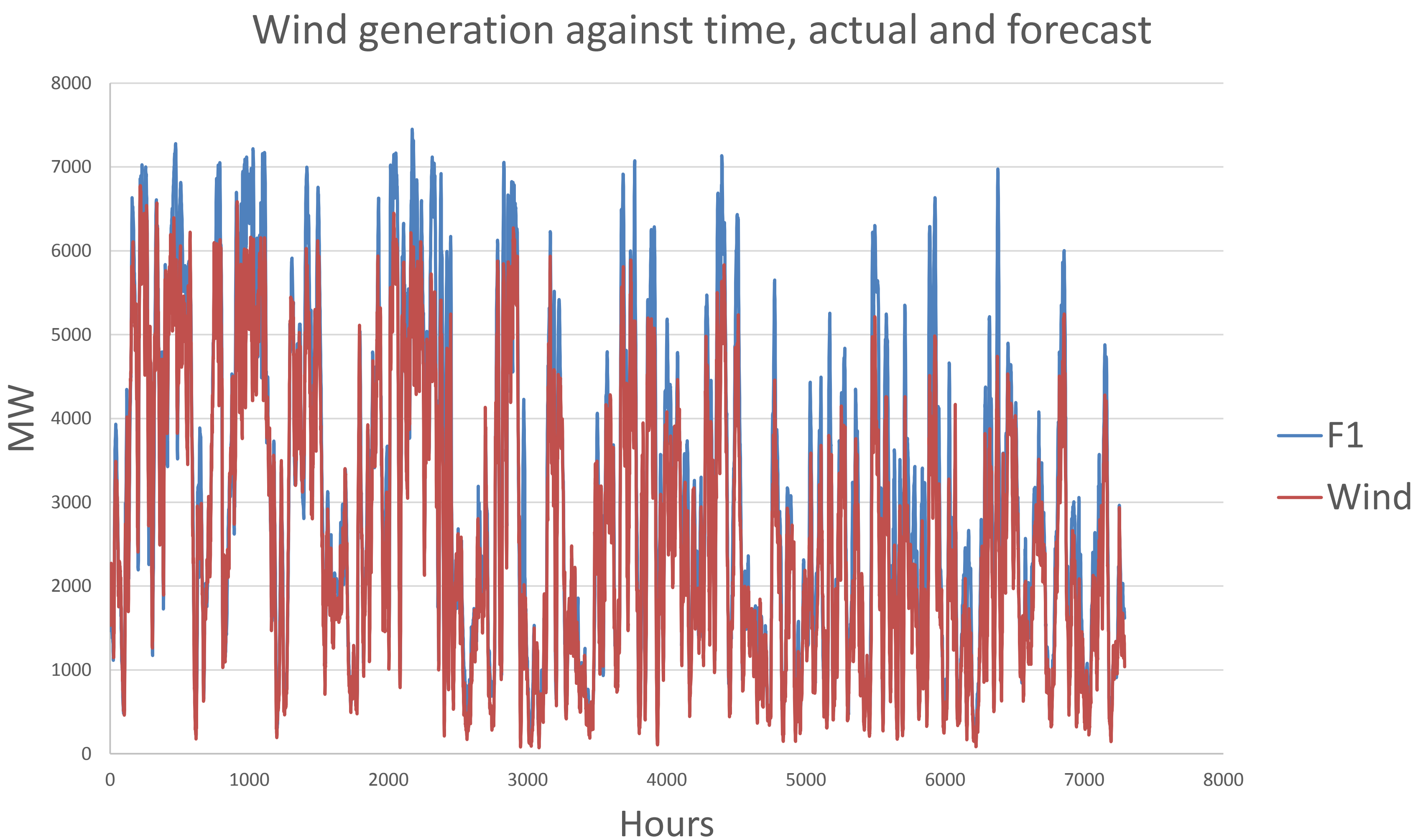
- As wind power increases in importance in Britain, supply becomes less certain, less biddable and less closely linked to demand.

The variability of wind generation- market impact

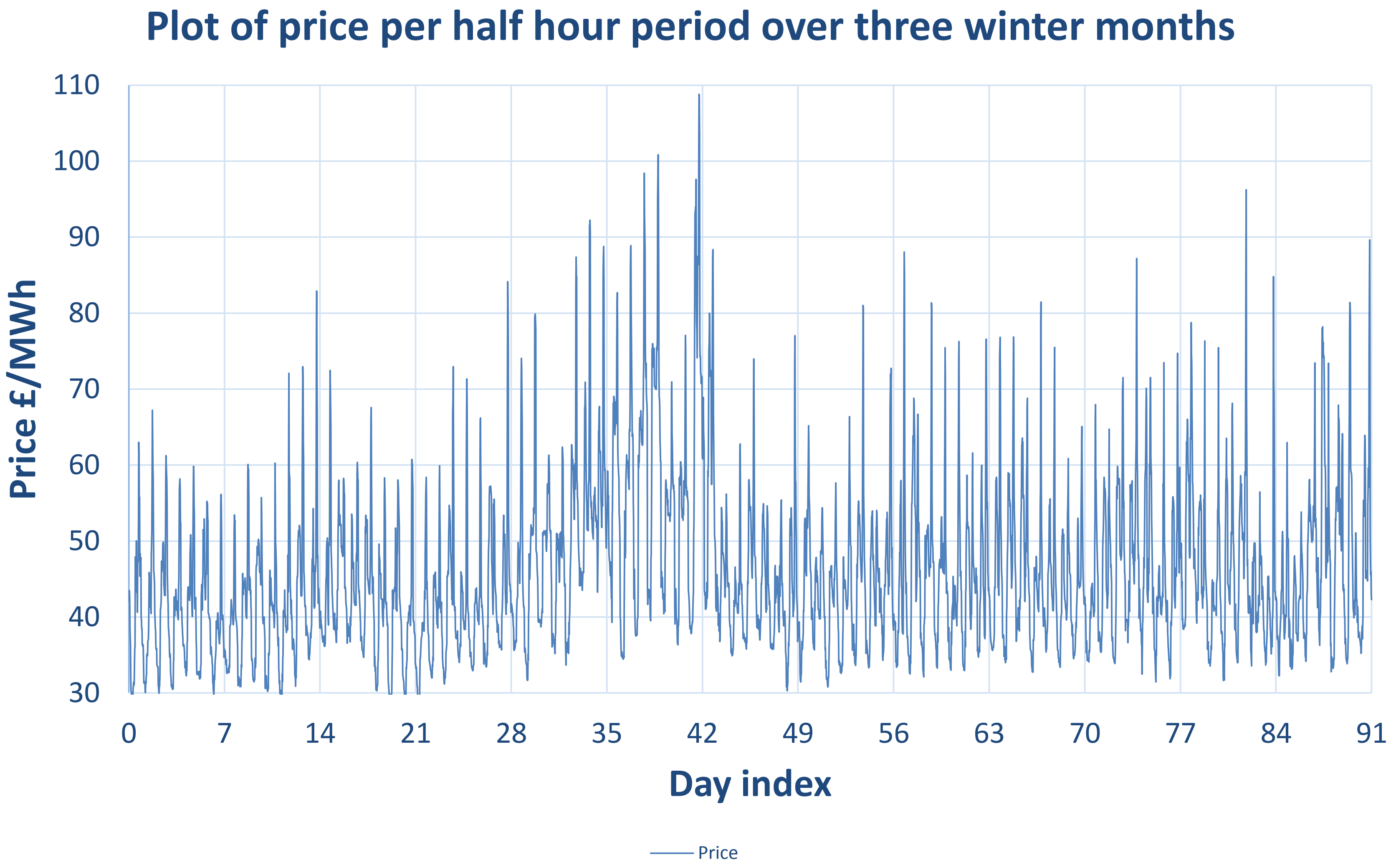


Short-term forecasting is not a big problem

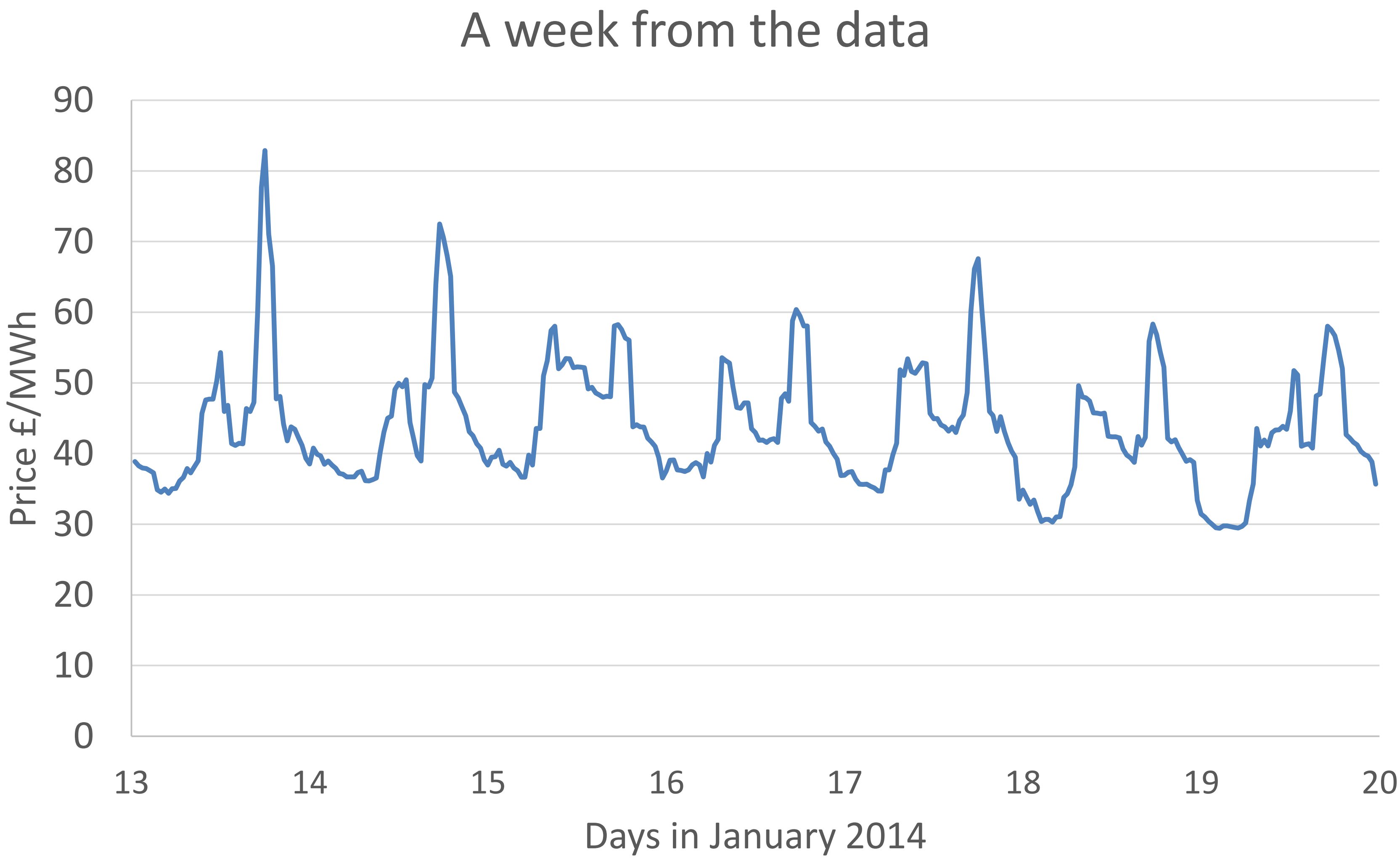
Variability over a longer period

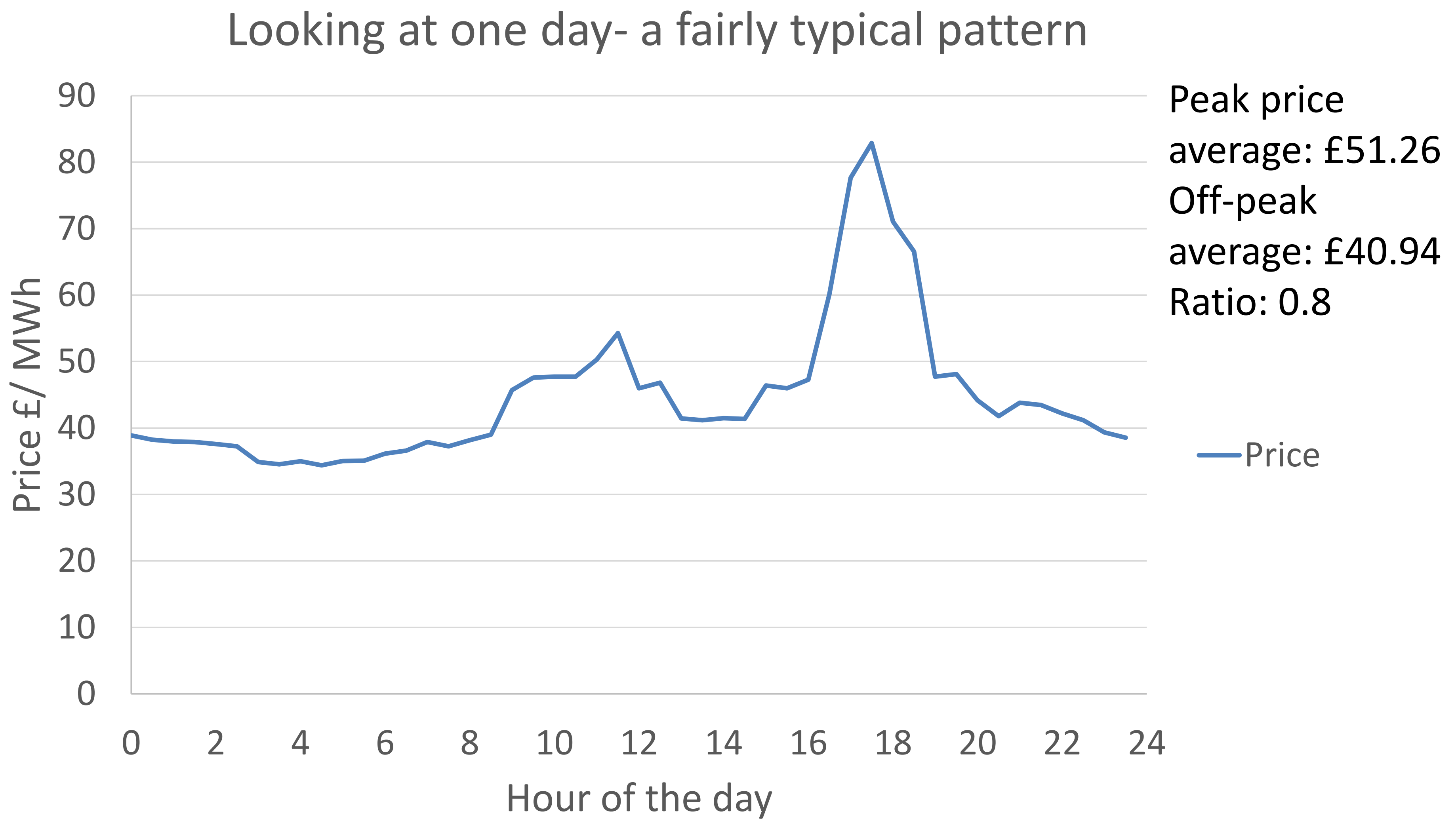


How does this match with prices?

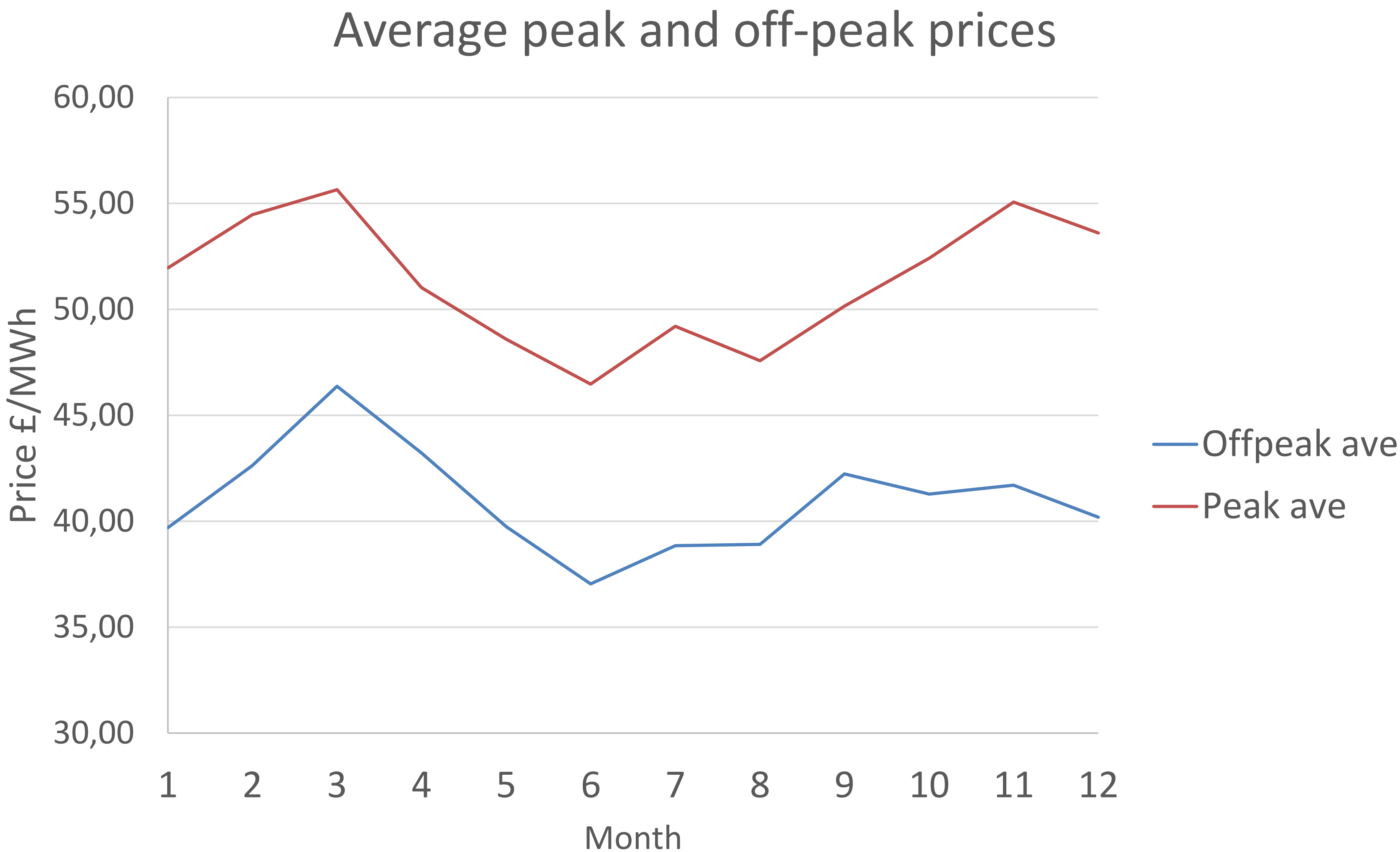


Focusing in on prices




Looking at one day- a fairly typical pattern
90
80
70
60
50
40
30
20
10
0
Price £/ MWh
0
2
4
6
8
10
12
14
16
18
20
22
24
Hour of the day
Peak price average: £51.26
Off-peak average: £40.94
Ratio: 0.8
Price

The opposite extreme



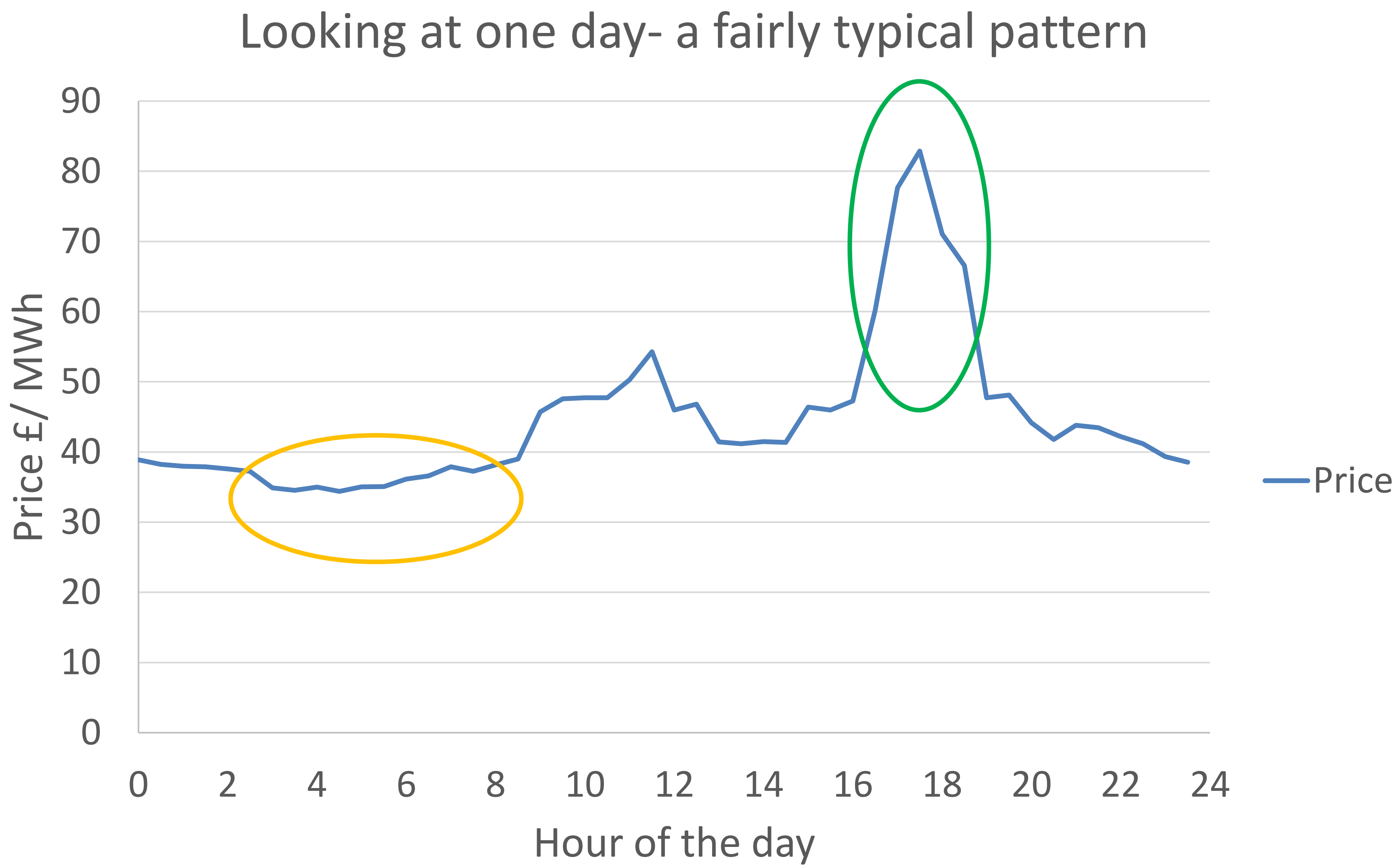
Relatively small dispersion over the longer-term

Implications of the pattern of prices

- Prices are very variable over time- this means there is scope for arbitrage
- The main variability is diurnal; there is little variability over longer periods of time, so little scope for long-term
- The diurnal variability is not simply between peak and off-peak (see Giulietti et al, 2013)
- There are relatively few periods in which prices are very high
- Price "never" drops to zero.
- Further implications:
  - A more subtle strategy is needed to make money from arbitrage, if the vehicle is somewhat inefficient
  - Grid Wind is not "free" in opportunity cost terms

Would commercial storage operate this way?

- A common perception is that *commercially funded* storage would focus (like interconnection) on arbitrage between high and low prices for electricity.
- In practice, this means focussing on diurnal variation for much of the time, *assuming* prices follow a similar pattern to those in the past.
- The diurnal variation needs to be quite subtly managed.
- This may be an unwarranted assumption (which we examine shortly), but it is still likely the case that the highest SMPs are at times when marginal fuel generators are brought into play.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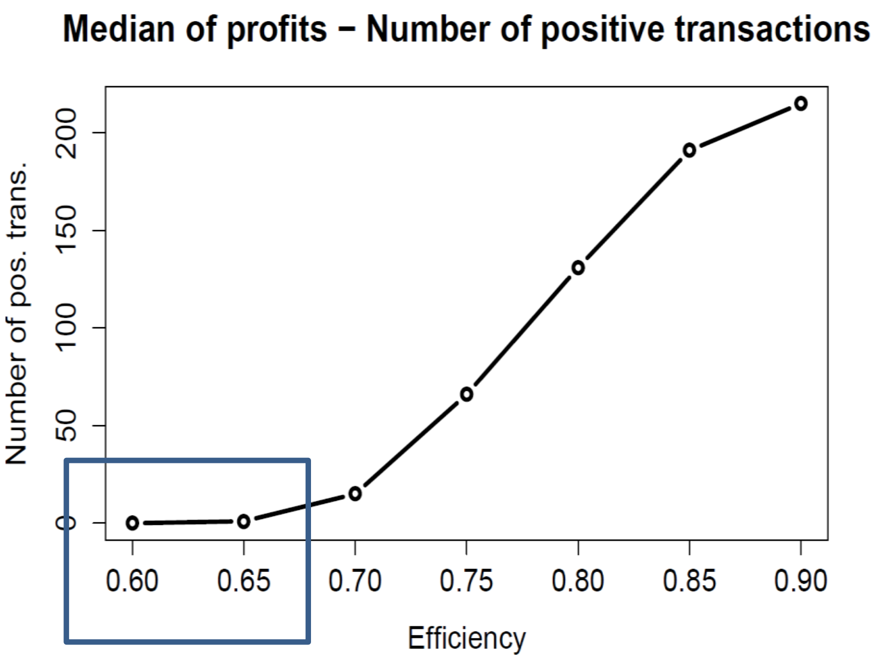
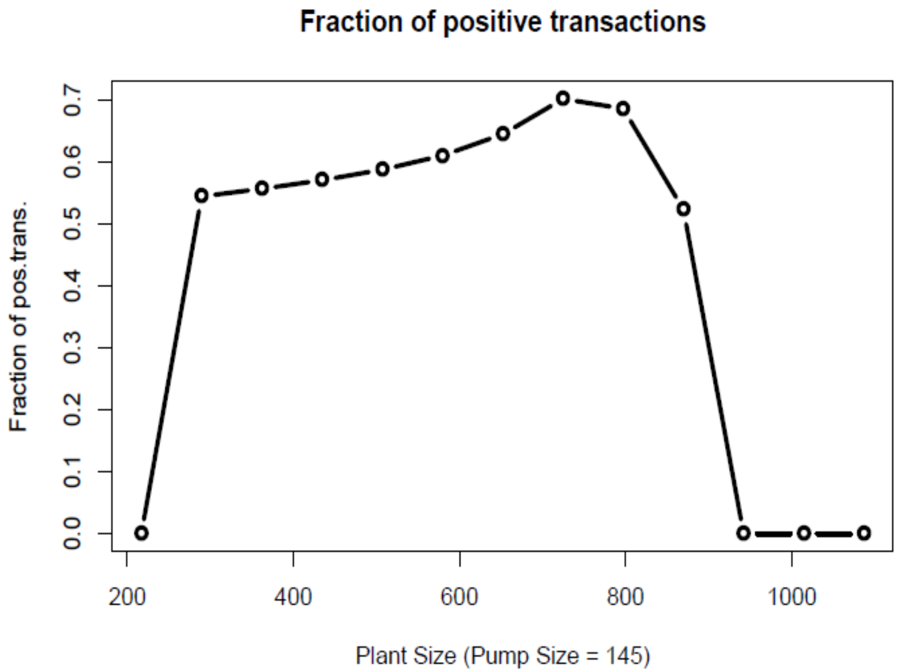
Capturing the benefits requires buying for a few periods in the night, selling for a few periods over the day, *if the store is reasonably efficient*.

Key determinants are efficiency and plant size to pump size



At low efficiencies, other approaches would be needed



(This is for a 90% efficient store)

Implications and caveats

- There is money to be made out of storage, so long as the store is relatively efficient and it is operated so as to inject into storage for a few periods in the night, and to discharge over a few peak periods in the early evening
- This implies that the store should be small relative to the injection rate, capable of retaining only around 5 hours of input
- We have ignored construction costs
- We have ignored any effect of the store on prices, or any interaction between the store and other stores or generators etc. These effects are likely to reduce profitability.

Three questions

- So commercially operated storage will store for a few hours at night, discharge for a few hours probably in the evening peak

1. Is the operation of storage in this way socially optimal?
2. Is this focus likely to continue in future, or will peak to off-peak gap increase or decrease?
3. Will prices grow rapidly more sensitive to wind forecasts?
   – What about forecasts more generally?

$-\beta\theta > \sigma$

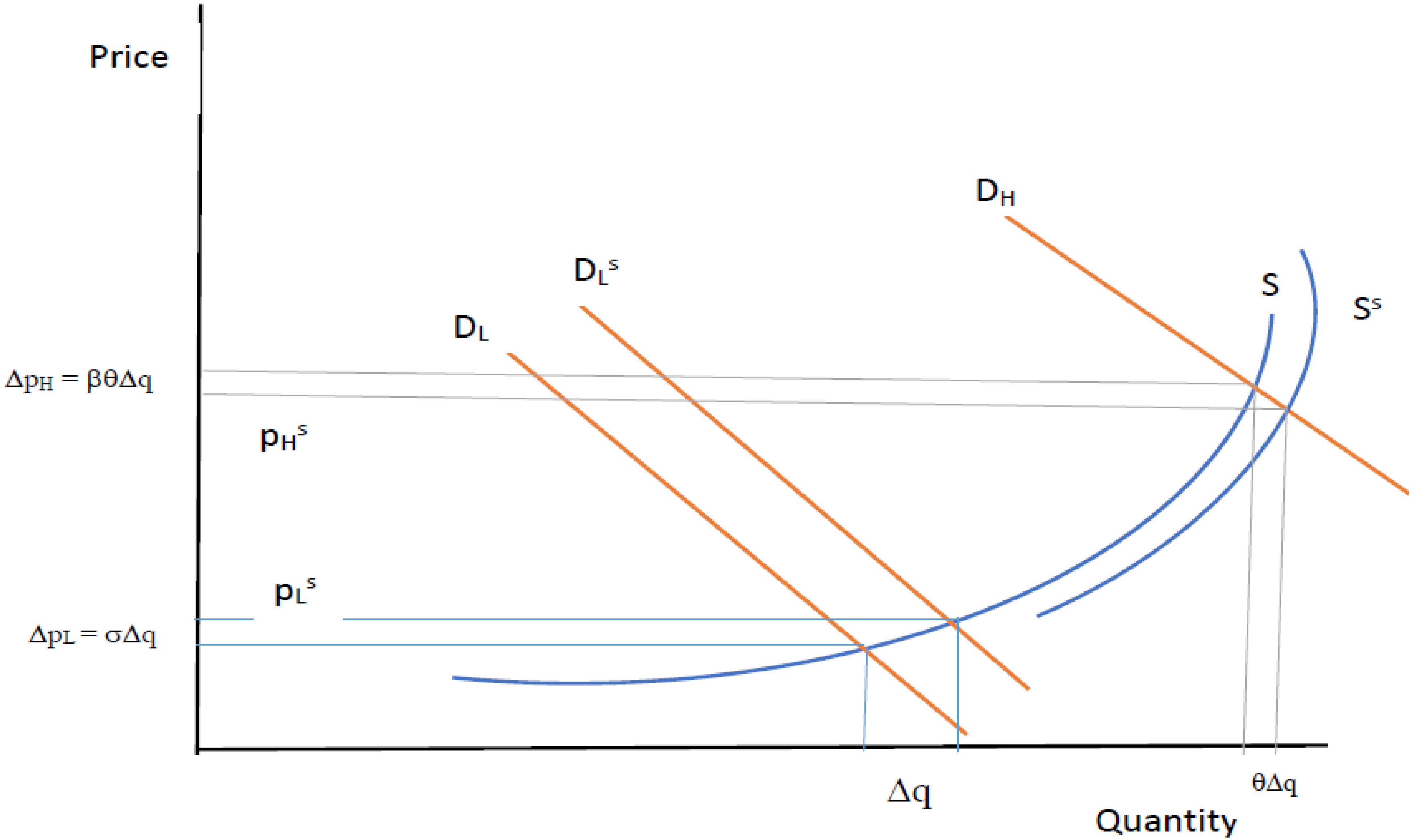
1.Social optimality of commercial storage is not assured (1)

- Necessary condition for private profitability:

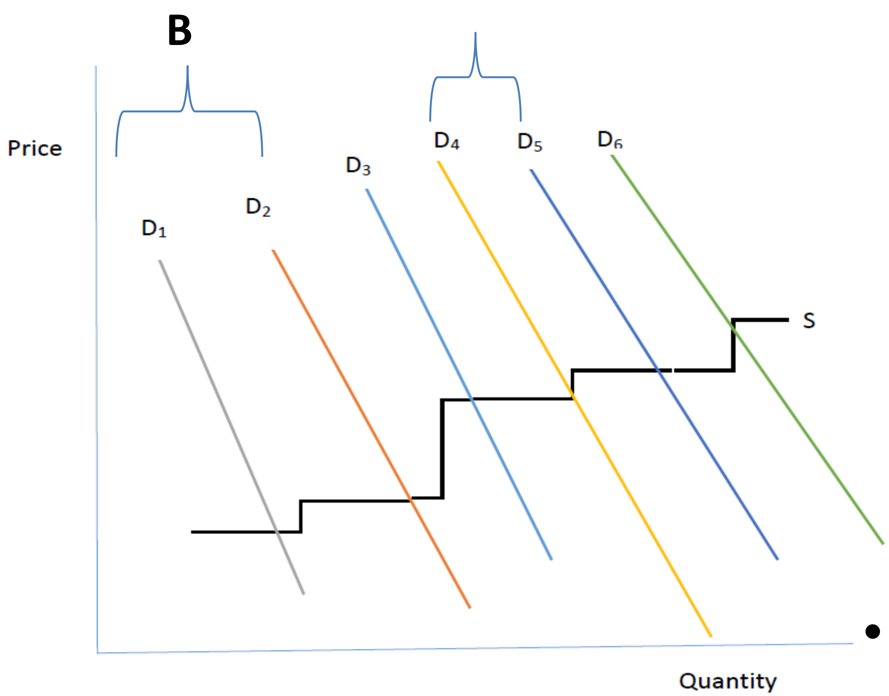
$$p_H^s > p_L^s / \theta$$

- Here theta is efficiency of the plant
- Sufficient condition for social optimality:
- $$-\beta\theta > \sigma$$
- Here, sigma is the slope of supply at the low end, beta is the slope of demand at the higher end
- Quite a different condition, although often likely to be met
- Diagram to explain (results assume away change of change)
- If supply inelastic, the sufficient condition becomes necessary.

Social optimality of commercial storage is not assured (2)



2. The peak to off-peak gap



- It is not necessarily the case that the gap between day and night prices will increase, as nuclear baseload output declines; in Germany, the diurnal variation has *decreased* post-Fukushima because of reduced nuclear baseload, despite increased wind generation.
- More generally, it depends on which plant is retired and the jumps in the merit order.

3. Sensitivity to wind forecasts (1)

- If prices react significantly to wind forecasts, then the storage incentives may change, for example to longer-term considerations
- Estimation of the equation $p^f_{t+1,t} = g(L^f_{t+1,t}, W^f_{t+1,t})$
- For the period from November 2014 to September 2015, instrumenting for load using time of day and day of week instruments
- Results: The elasticity of price with respect to the wind forecast is just over 0.1.
- In other words: a 1 standard deviation change in the forecast for wind, at the mean, would result in a change in price of £1.63, where the average price is just over £40 per MWh.
- So wholesale price *is* sensitive to wind, but *not sensitive enough* to change strategic thinking
- Estimates from Ireland, where there is over 20% wind (and similar climatic conditions) also suggest relatively low sensitivity.
- Longer-term forecasts are problematic.

The technical details (2)

IV regression of forward price (p) on forward load and forecast wind		
	Coefficient	st error
Load	$7.41*10^{-4}$	$1.87*10^{-5}$
Wind	$-1.45*10^{-3}$	$-5.92*10^{-5}$

Notes:
7290 observations. Rsq 0.304
Instruments for Load are day, time, squares and cubes of these, interactions between these.
The Rsq for the first stage is 0.735

We are able strongly to reject the presence of a unit root in Price, using the Augmented Dickey Fuller

test with up to 25 lags. Similarly, we are able to reject a unit root in Wind.

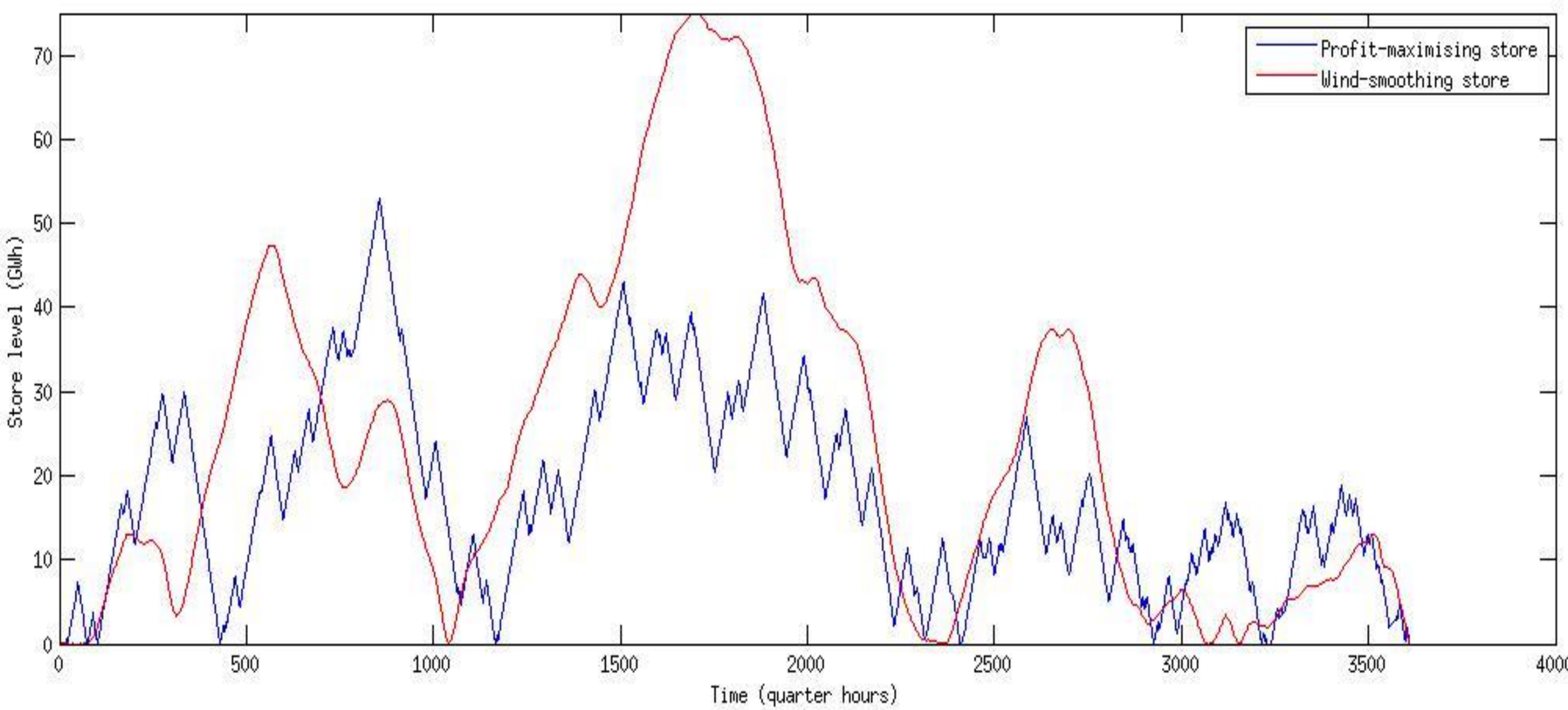
Are pricing signals available to encourage longer-term storage? (3)

- Do (say) this week's forward prices for delivery next week indicate that there will be a large/ small amount of wind?
- So, is there anything in the (increased) forward prices that captures (anticipated lack of) wind; are forecasts good enough?
- We currently do not have forecasts for next week
- Taking UK WA forward prices (Platts' assessments) and the amount of wind generation actually occurring next week, do a simple regression (includes a trend to capture increased amount over time) over these 3 years in Britain.
- Essentially, no correlation between the two variables; no signal

Conclusion

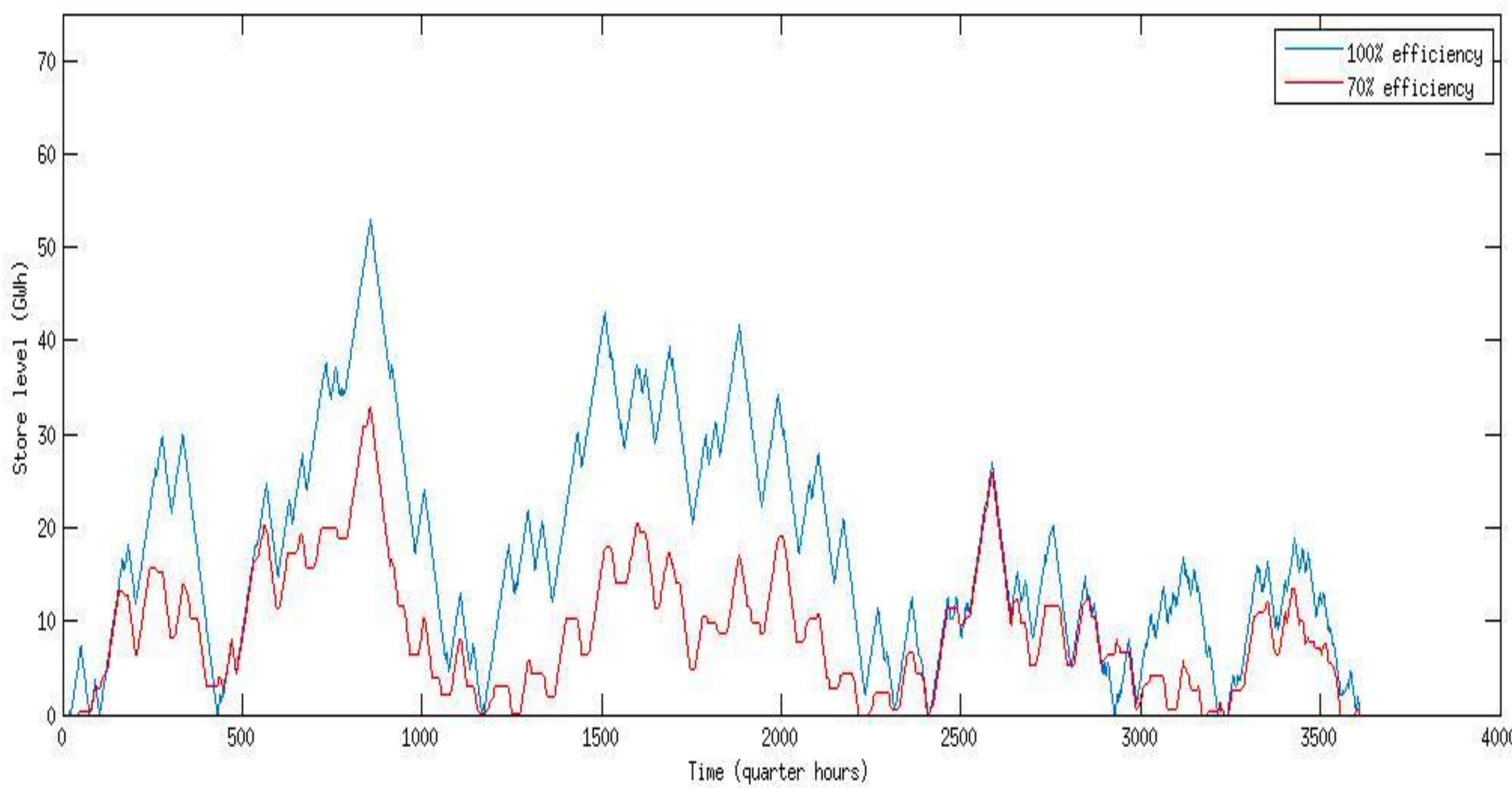
- Storage as arbitrage may have some impact in diurnal peak-lopping
- Its main competitor is interconnection, which is less well adapted but more efficient
- It will have no impact on longer-term factors
- It is not clearly always beneficial
- Some other mechanisms may need to be adopted in order to smooth out the market in the face of significantly increased renewables
- For example the capacity mechanism could be adapted to encourage storage.

Comparison of smoothing and arbitrage scenarios



The store has capacity 75GWh and the same charging (discharging) rates, 1.04GW (1.25GW) in each case. The complete sequence of prices is known Notice that the level smoothing scenario involves more use of store capacity and significantly fewer fluctuations

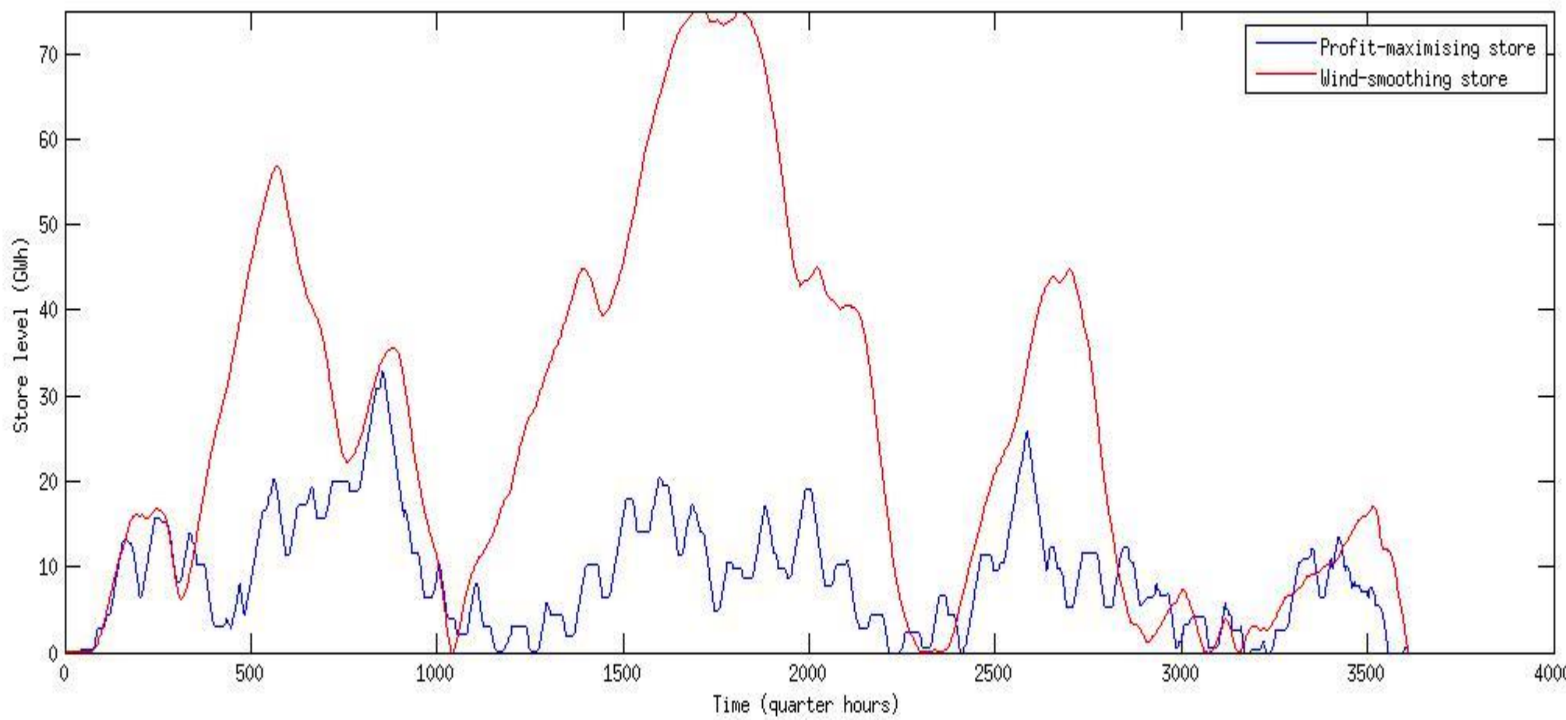
How does the profit max store behave if it is less than 100% efficient- example with 70% efficiency



Why the difference in approaches?

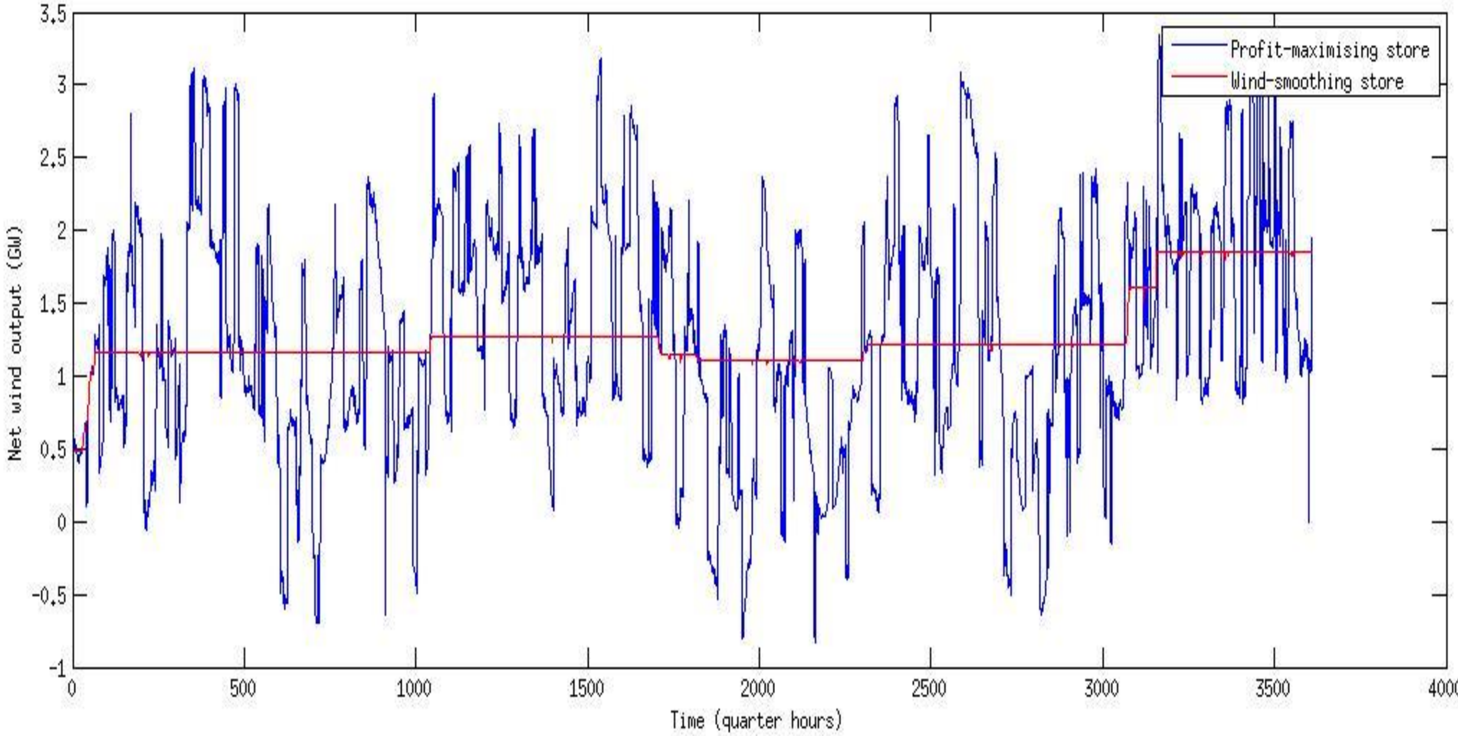
- The store makes money by moving power in and out of store, not keeping it there
- The profit max store at 100% efficiency earns gross profit, before pumping costs and capital costs, of 14.8M€. The smoothing store incurs losses of 2.74M€, though.
- This will clearly be reduced if the store is less than 100% efficient, though; a store that is 70% efficient operated commercially earns 6.38M€, before labour and capital costs.
- The store is smaller under commercial operation- this is not here due to monopoly reasons; the profit max store does not require its full capacity. Rather it is due to the power restrictions and the fact that prices are fluctuating sufficiently swiftly that the store can does not have time to completely fill, unless larger power.
- Consumers do not necessarily benefit from control of these short-term, diurnal fluctuations (diagram to illustrate this, later slide), although the firm does

Store behaviour under 70% efficiency



Here capacity is still set to 75GWh, but the power rates are set to allow smoothing, to 1.09GW charging and 1.14GW discharging. These are the smallest rates that allow the store to smooth as much as possible. (The rates vary as efficiency is varied.) The difference is starker.

Impact on net output level from wind under 70% efficiency



The range is not as large here, because both stores are less efficient. However, the big difference in the outcome from the strategies is still apparent.

Implications

- Arbitrage is the natural target for a commercial store (as for interconnectors)
- However, short-term arbitrage does not deal with the longer-term storage requirements and may not be in consumer interests generally
- Consumers would benefit, and network operation would benefit, from longer-term storage to create some inertia in the system that is removed by a move to renewables
- Without this, the alternative is to burn a lot of gas, to keep the system in operation over periods where renewable plant is producing too little.
- But unless price relativities change significantly, storage will not arise to meet this need under separate commercial store ownership.
- This would be difficult to achieve unless accurate long-term wind forecasts are available, and influence forward prices, otherwise the information to hold power in reserve would not appear in the forward price data. Key issue!