

# **Intermittency and the social benefit of storage**

Monica Giuliatti

(with E Trujillo Baute and M Waterson)  
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# The economic value of storage

- For the Government/regulator: avoided wind curtailment cost and reliance on back up facilities
- For the storage company: maximum expected profit
- For the system: electricity price reduction as price spikes are avoided during wind calm
  
- Our analysis focuses on the last issue and is technology neutral

# Social benefits

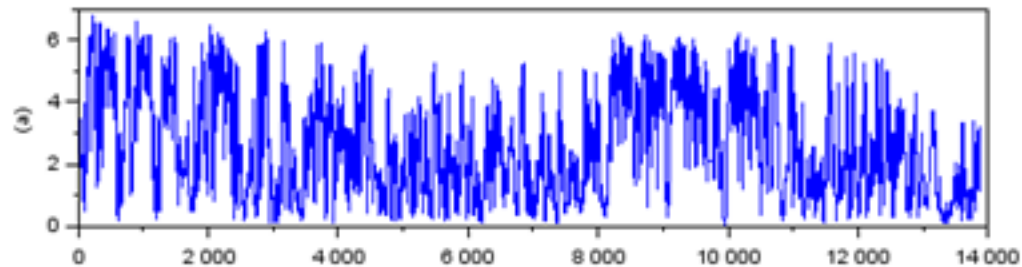
- The social benefits include in principle:
  - Saving capital expenditure on new peaking plant (at the expense of increased storage construction costs)
  - Reduced expenditure on grid reinforcement
  - Avoiding some curtailment of renewable energy
  - Fuel saved through reduced ramp rates
  - Reduced need for low efficiency plant to operate
- Essentially, there is a missing market problem due to uncaptured positive externalities

# The problem to be addressed

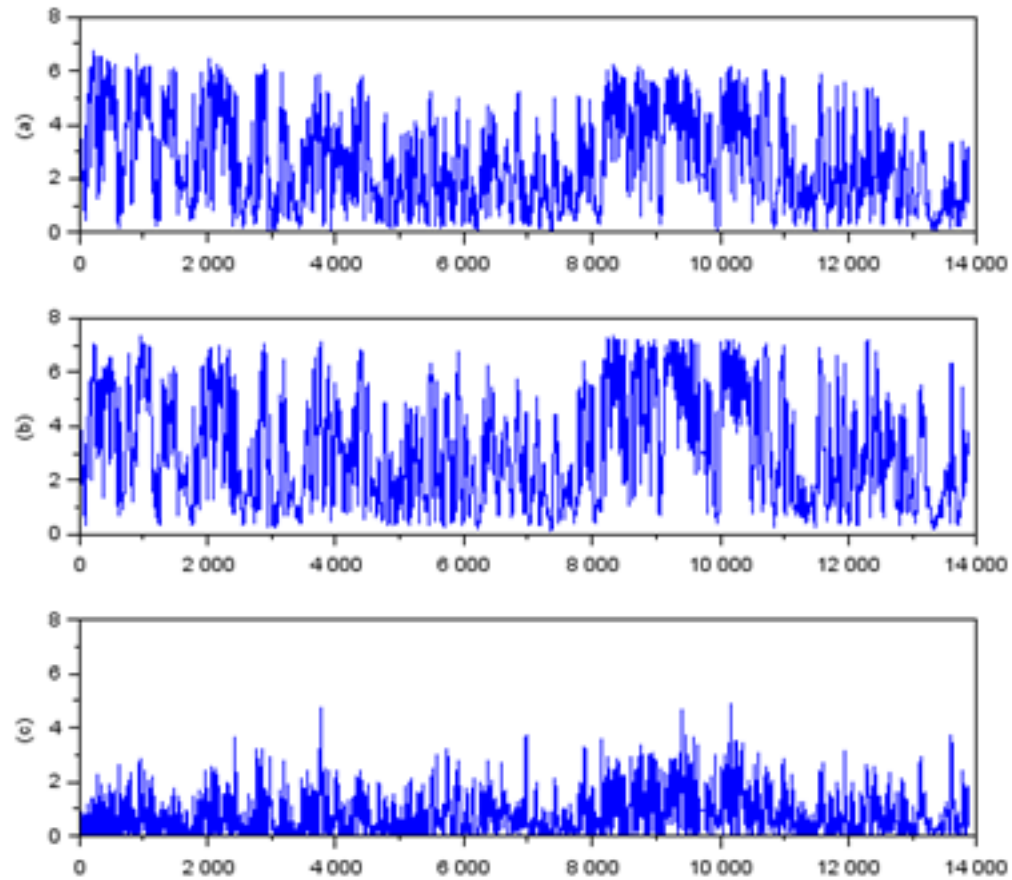
- To identify the potential social benefits from storage – market information
- Capital expenditure and grid reinforcement on a side, not observable
- -missing information - capacity market approach
- Focus then on ramp rates & efficiency
- Context - the grid-scale store is used to attention wind generation and absorb forecast errors
- Therefore, mitigating the wind impact on market prices level and volatility

# Intermittency

Wind output - variability (UK Dec. 2014 - June 2016)



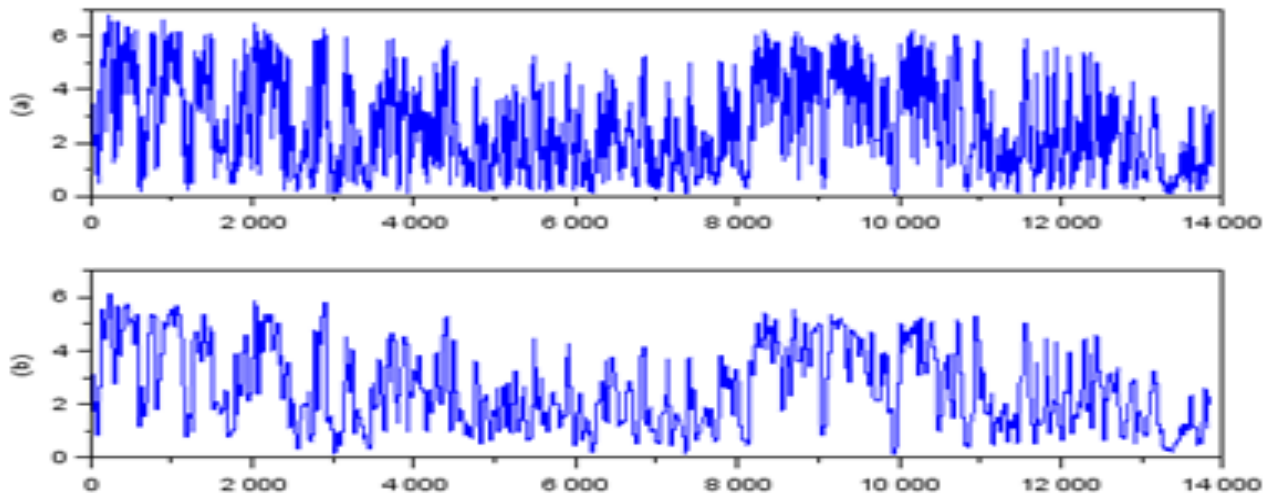
# Forecast error (December 2014 –June 2016)



# Research Question

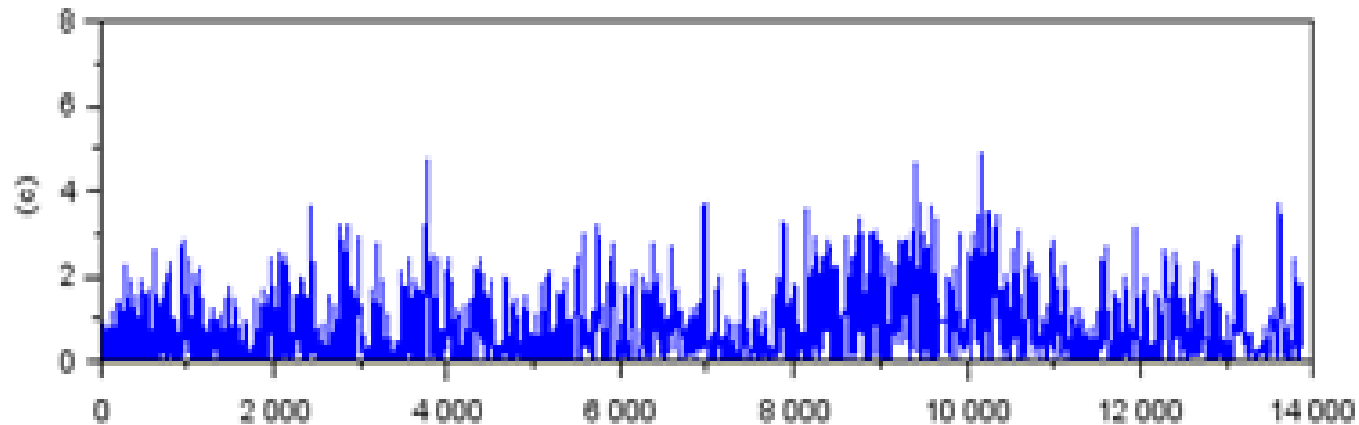
What are the market price effects of introducing a grid-scale store capacity sufficient to absorb wind generation impact on prices?

What happens if we transform the wind hourly generation into a smoother baseload plant generating the daily average?



# Research Question

And a plant which can absorb the wind forecast error?



# Empirical approach: Markov regime switching model

- Analyse price effects of store capacity sufficient to absorb wind generation impact on prices
- Two models:
  - First - The impact of wind
  - Second - Grid scale storage
- Comparison
  - Price level
  - Price volatility

# Markov regime switching model - Wind

The market price

$$S_t = d_t + X_t$$

Deterministic component

$$d(t) = \mu_1 + \beta \theta_t$$

$$\theta_t = w_t / \mu_W - 1$$

- $\mu_1$ , the constant of the mean price level in the normal regime
- $\beta$ , effect of the relative deviation of wind at hour  $t$  from the day mean on the price level

# Markov regime switching model - Storage

The market price:  $S_t = d_t + X_t$

Deterministic component:  $d(t) = \mu_1 + \beta \tau_t$

State 1 – stochastic component

$$X^1_t = (1-\alpha) x_{t-1} + \sigma_1 \varepsilon_{1,t}$$

State 2 – stochastic component:  $X^2_t = \mu_2 + \sigma_2 \varepsilon_{2,t}$

Transition probability:

- $\tau$ , store with 70% efficiency
- $\beta$ , effect of the store on price level
- 1 and 2, effect of the store on the state transition probability

# Implications (price level)

	Storage	Wind	Difference
Peak			
Normal	37.057	40.556	<b>-3.498 (8.6%)</b>
Non-normal	44.212	46.291	-2.079 (4.5%)
Off peak			
Normal	29.021	28.097	0.924 (3.3%)
Non-normal	34.910	33.865	1.045 (3.1%)

# Implications (price volatility)

	Storage	Wind	Difference
Peak			
Normal	0.080	0.082	-0.003 (3.7%)
Non-normal	0.267	0.773	<b>-0.506 (65.5%)</b>
Off peak			
Normal	0.073	0.074	-0.001 (1.4%)
Non-normal	0.375	0.989	<b>-0.614 (62.1%)</b>

# Implications

Combining:

- Simulated prices and probability of states

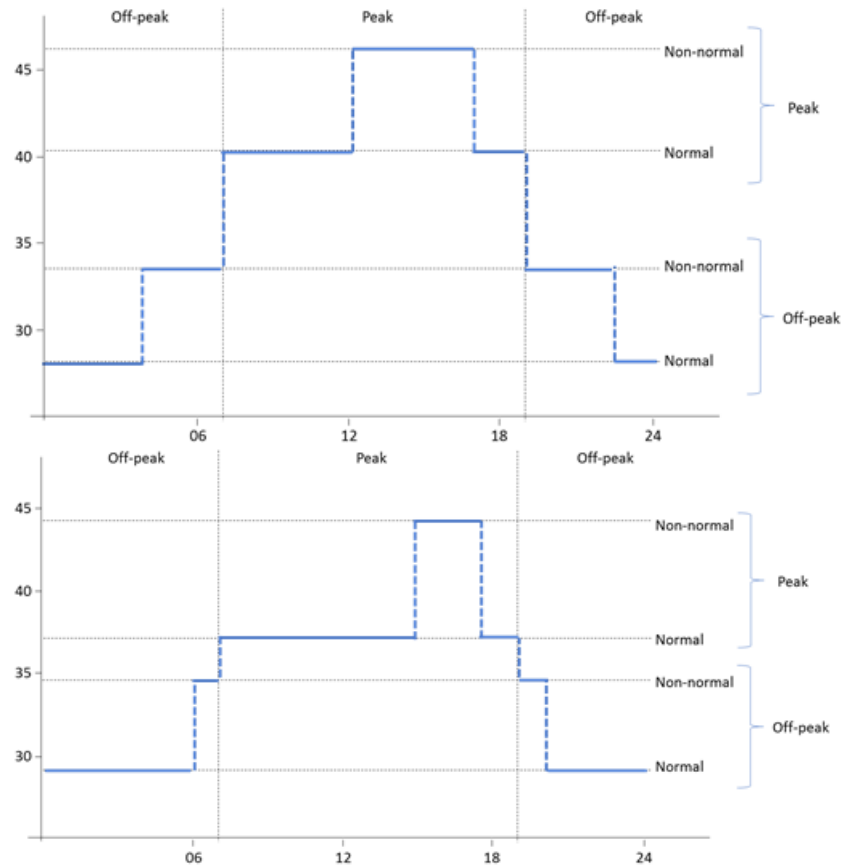
Simulated weighted average prices (£/MWh)		
	Wind	Storage
Peak	43.06	38.82
Off-peak	31.27	28.94

Difference at Peak = 4.24£/MWh

Difference at Off -peak = 2.33£/MWh

Mitigating intermittency effects through storage captures the value of flexibility

# Implications (wind Vs storage)



# Conclusions

Introducing grid-scale storage to flatten wind into a baseload generation will:

## Prices and Volatility

- ↓ Price level of normal and non-normal reg. → saving for consumers
- ↓ Price volatility of non-normal regime → spikes are softer and predictable

The lower volatility of non-normal reg. combined with the lower mean price implies that the market will become more stable

## Probability

- ↓ spikes probability
- Once we have a spike the probability of returning to the normal price "
- It will be more likely to face lower and more stable market prices
- Assuming that effects on market prices are passed-through to final consumers, hence social benefits from storage

# Thank you

[m.giulietti@lboro.ac.uk](mailto:m.giulietti@lboro.ac.uk)