

Market Behaviour with Large Amounts of Intermittent Generation

(preliminary – please do not quote without permission)

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Background and motivation

- EU renewables target by 2020: 20%
- For UK:
 - 15% renewable energy
 - c. 40% renewable electricity...
 - ...great part of which is likely to be wind.
- Impact on market prices? profits? risks?
- Precursor to a study of investment...

Literature overview

- Wind resource (e.g. Sinden (2007))
- Optimal investment in wind: Strbac et al (2007), Kabouris & Vournas (2004), Neuhoff et al (2008)
- Trading strategies: Bathurst et al (2002), Holtinnen (2005), Musgens and Neuhoff (2006)
- Impact on prices: Sensfuß et al, (2008)
- Market power: Twomey and Neuhoff (2005)
 - Wind generators receive less than average price of power
 - Market power exacerbates the inverse relationship between price and wind generation
 - Long term contracts may partly alleviate this effect

Data & Methodology

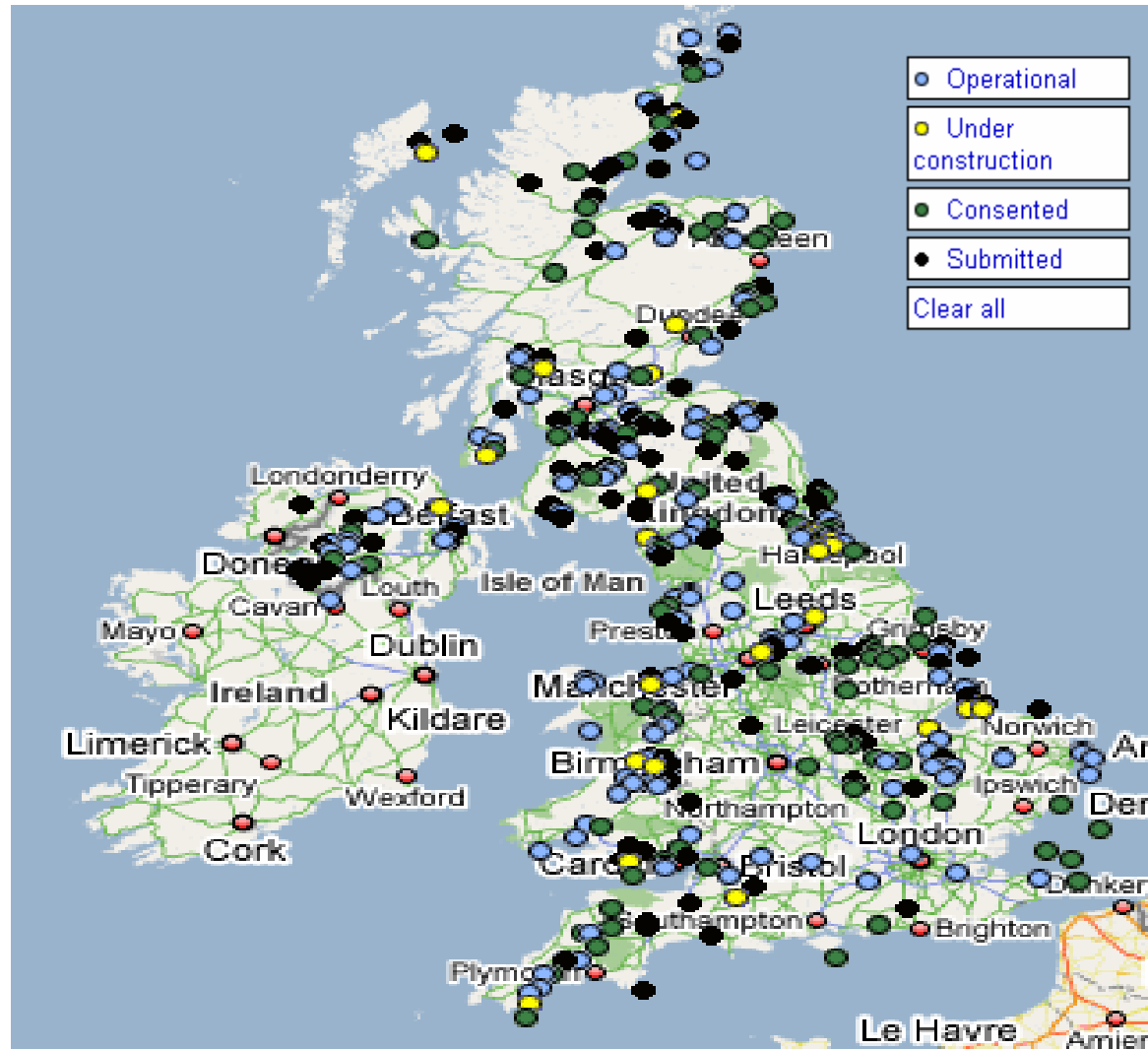
- Two components: theoretical model (based on Green, 2008; Yago et al, 2007) enhanced by actual hourly wind data for representative stations across GB.
- Hourly wind speeds drawn from Midas UKMO 1990-2005, which are then converted to output using standard conversion rules.
- Our dataset currently contains 15 stations, with at least one from each of the nine geographic wind regions as defined by BWEA.
- Earlier work confirms low wind speed correlations between selected regions.

Wind capacity in the UK (MW)

	S Eng.	N Eng.	Wales	S Scot.	N Scot.	Offshore	
Existing	237	166	305	642	525	404	
Constructing	49	114	16	535	117	457	
Consented	356	376	143	928	546	2270	
Application	314	634	299	2566	1528	2385	
Total wind	956	1290	763	4671	2717	2740	
Onshore	10396					Total	19152

Source: British Wind Energy Association

Wind farms in the UK (BWEA)



Thinking Networks

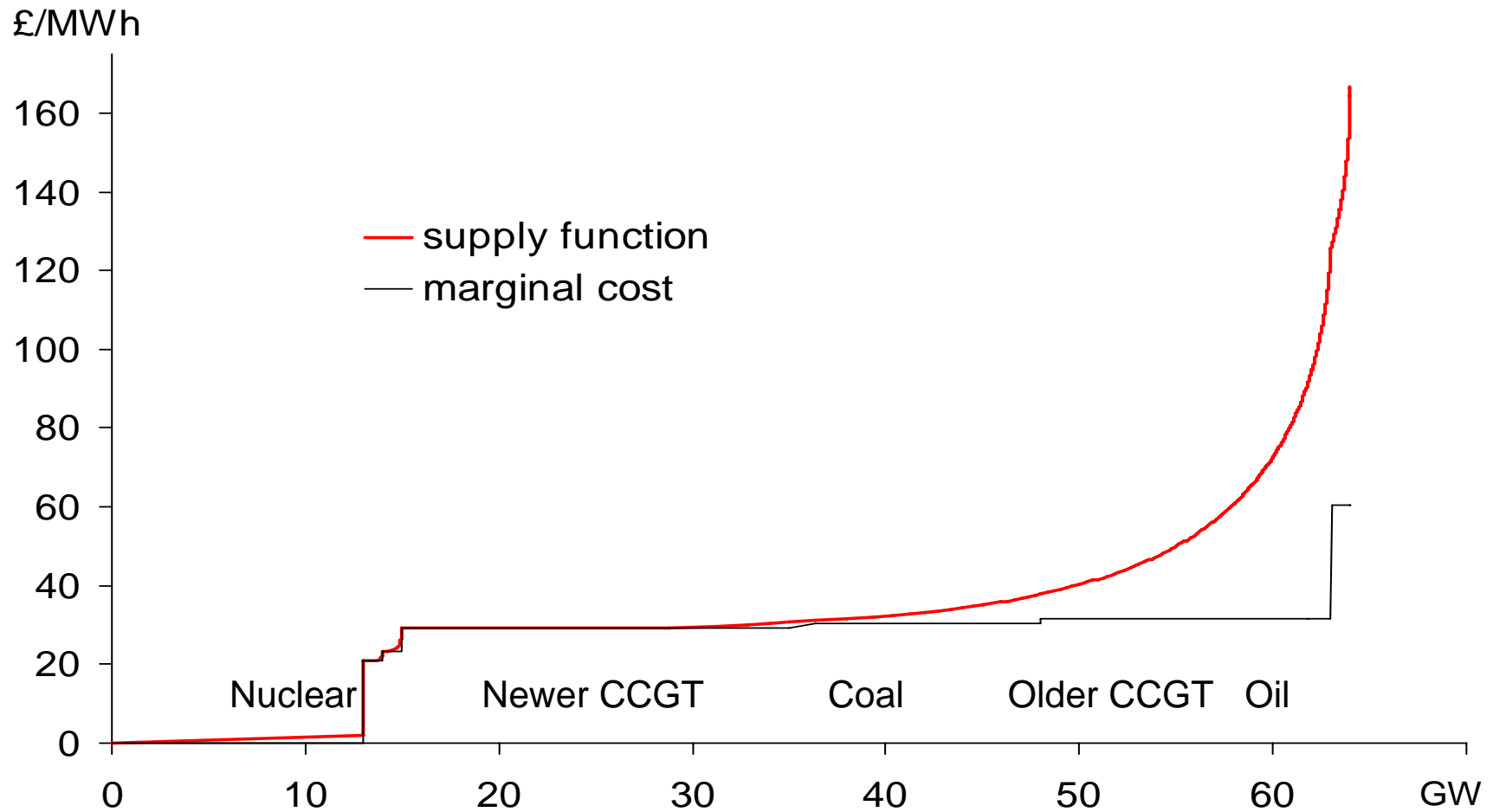
Selected wind stations



The Model - General

- Based on Green (2008) and Yago et al (2007).
- Symmetric generators compete in supply functions, offering a schedule of prices and quantities to the market.
- Nuclear stations treated as non-strategic
- Industry cost function based on data from “2006 Energy Review” (DTI, 2006) – by type of plant.
- Start-up costs are currently not included.

Industry supply function - thermal power





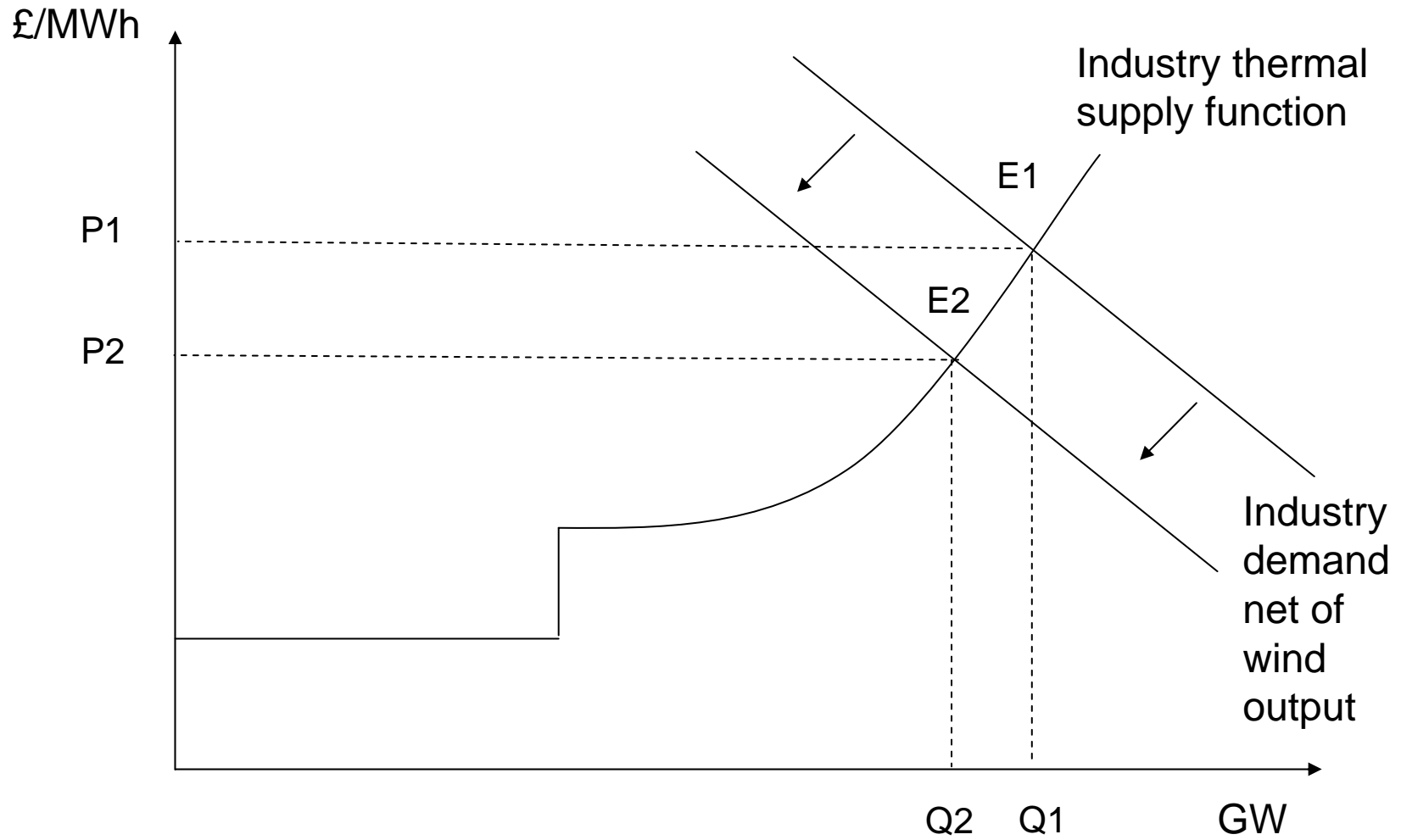
Renewable output

- Generation profiles for dispatchable renewable stations
- Wind output based on wind speed cubed
- Sample station output multiplied by regional capacity
- Offshore output based on national onshore output
- Profile for every day 1990-2005, by month

The Model – Equilibrium

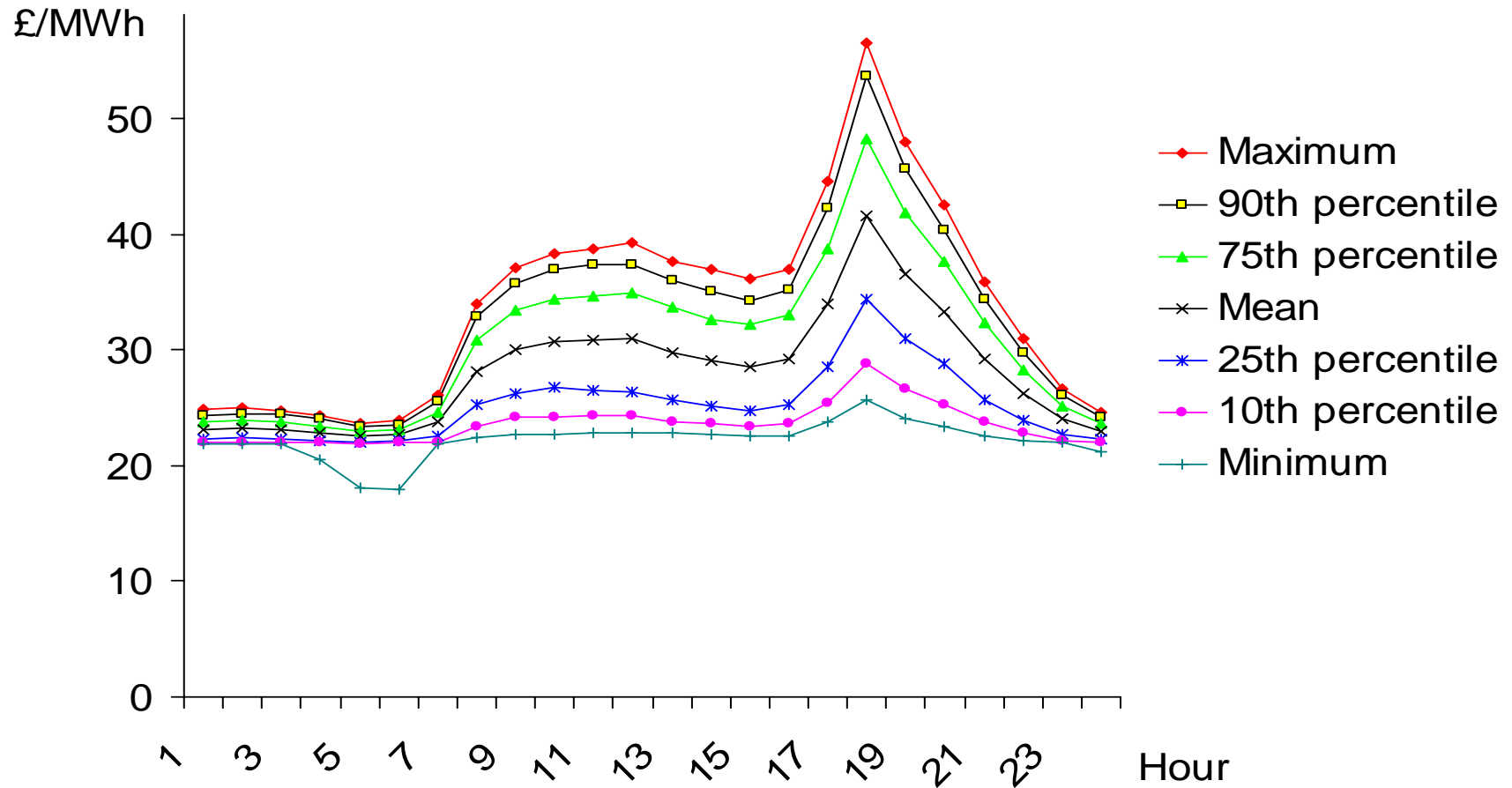
- (Hourly) Equilibrium prices determined by intersecting:
 - Thermal supply curves
 - Demand curves, net of renewable output:
 - Demands scaled up from average weekday demands and prices during January 2004
 - Assumed demand growth of 1.1% a year to 2020.
 - Linear demand slope of -80MWh per £/MWh
- Market power: two scenarios are currently considered; equivalent to 2 and 6 firms

Deriving market equilibrium



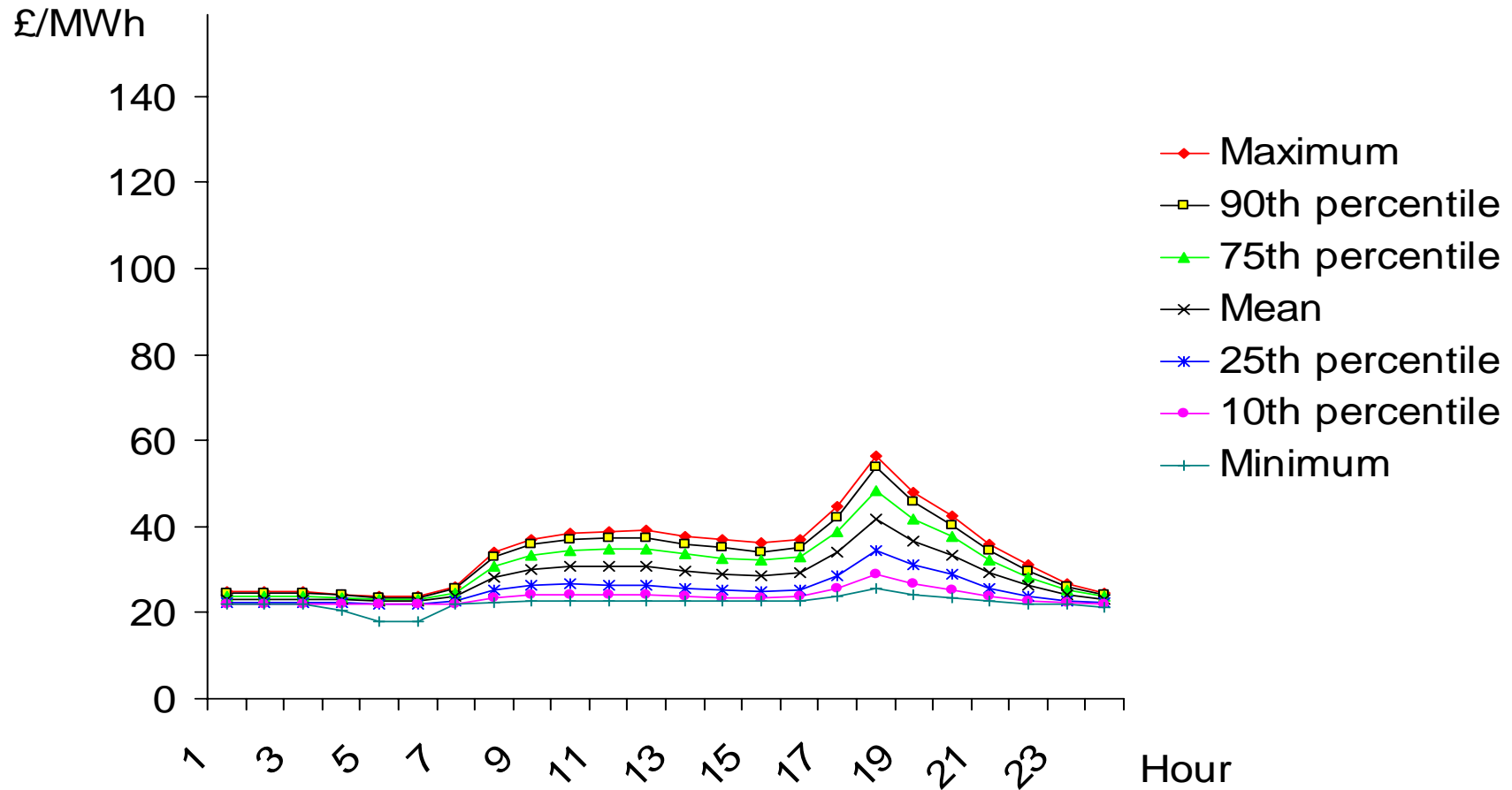


Price variation due to wind - 6 strategic firms



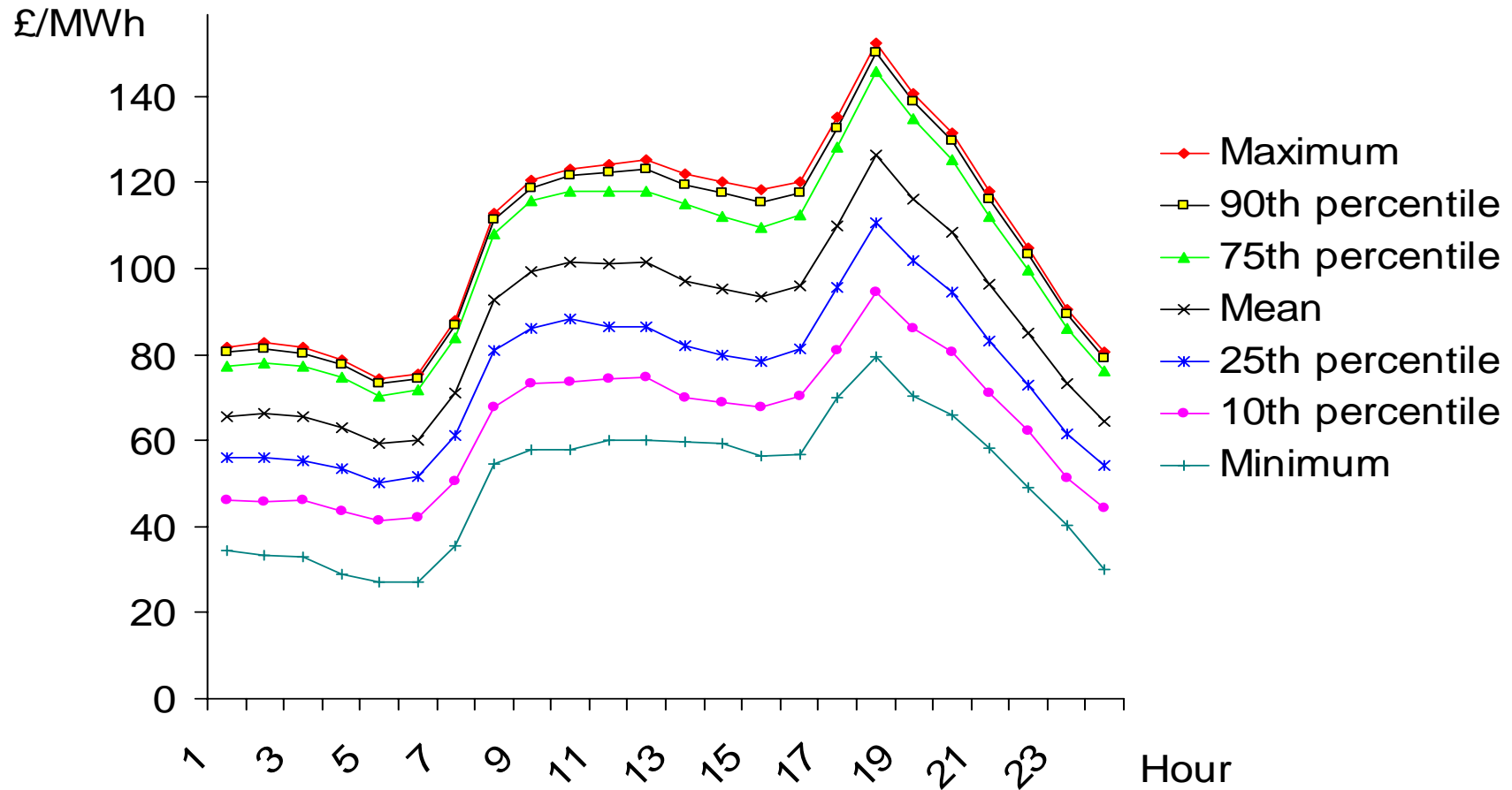


Price variation due to wind - 6 strategic firms



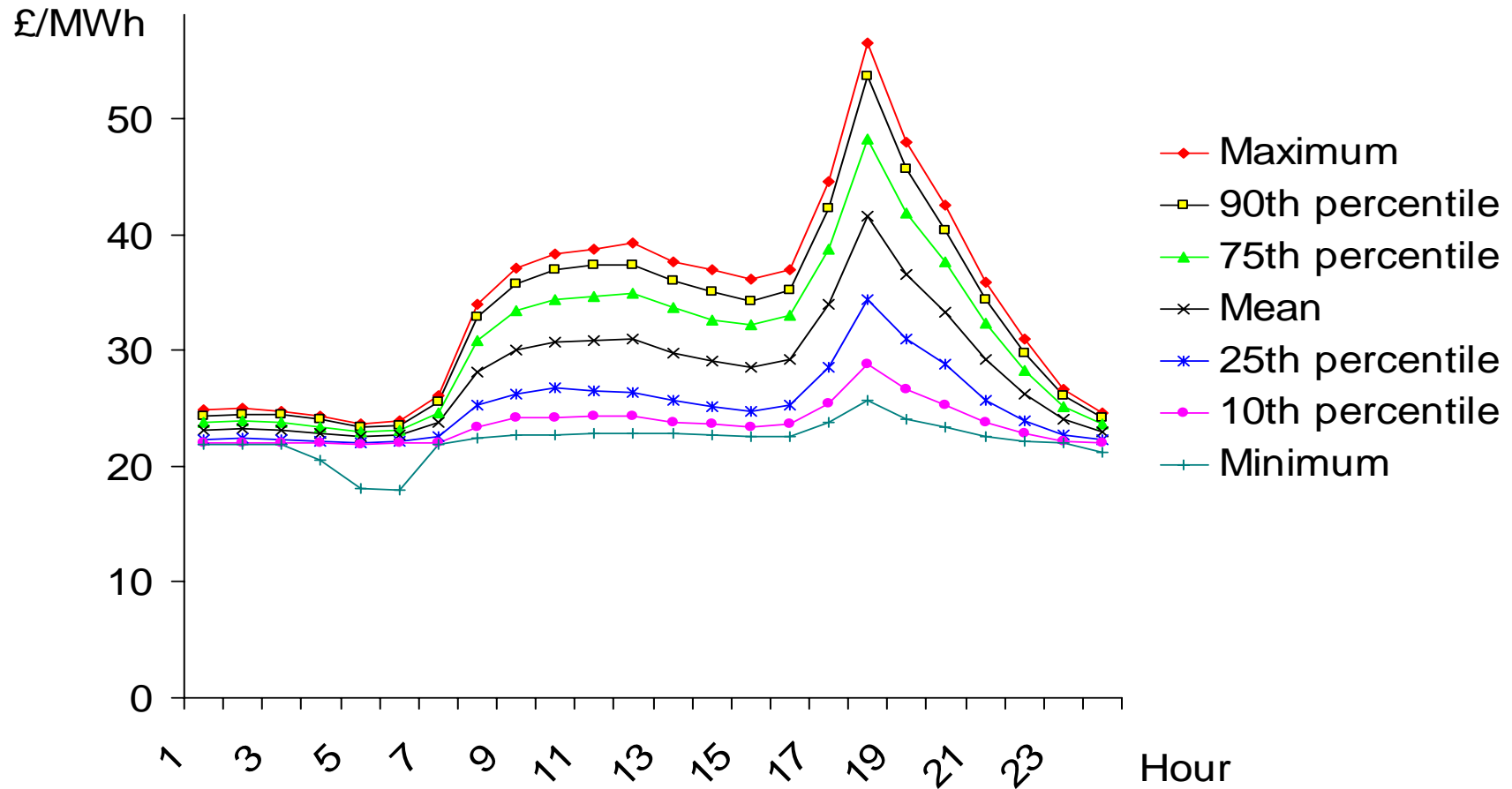


Price variation due to wind - 2 strategic firms



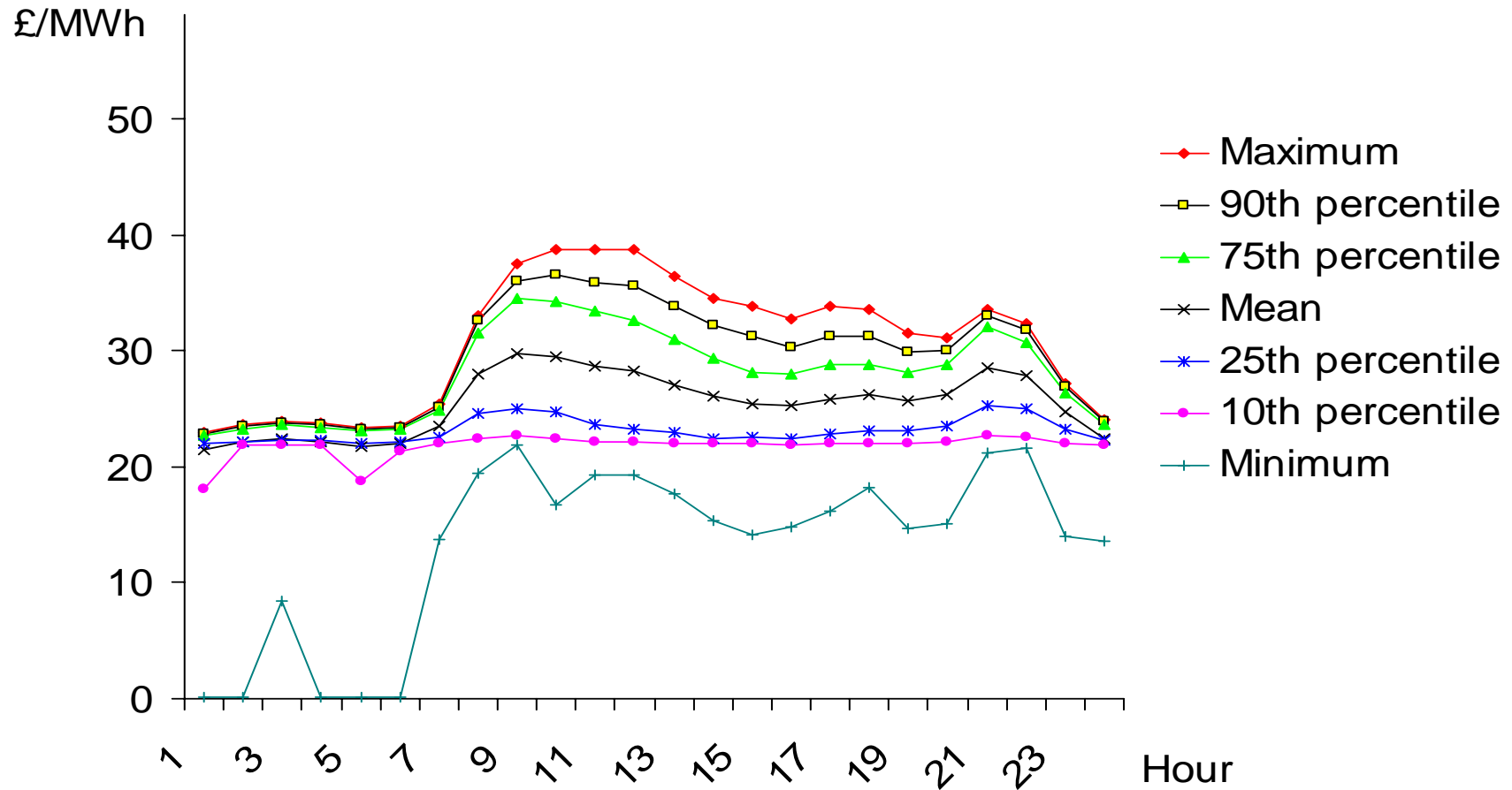


Price variation due to wind - 6 strategic firms



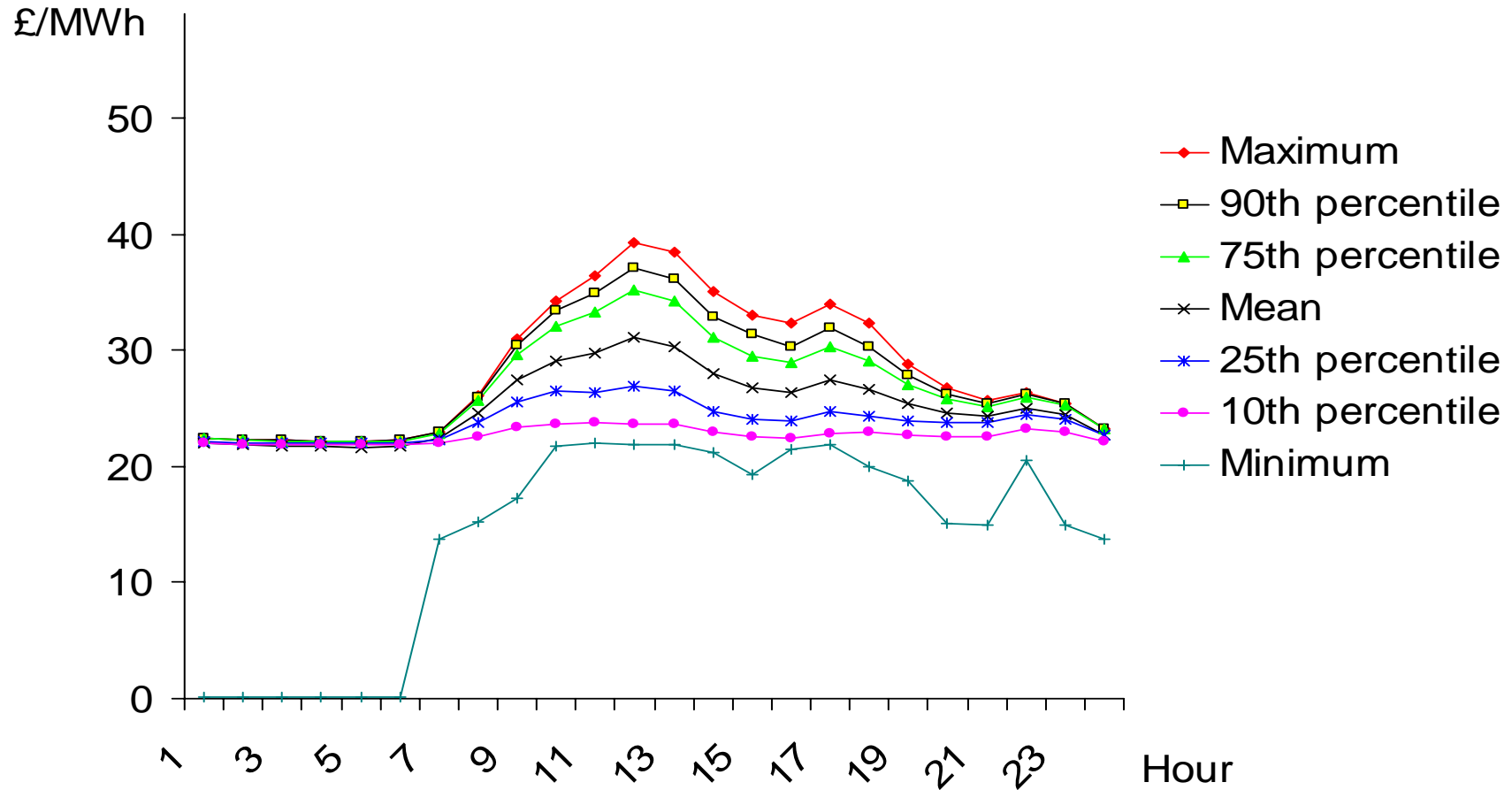


Price variation due to wind - 6 strategic firms



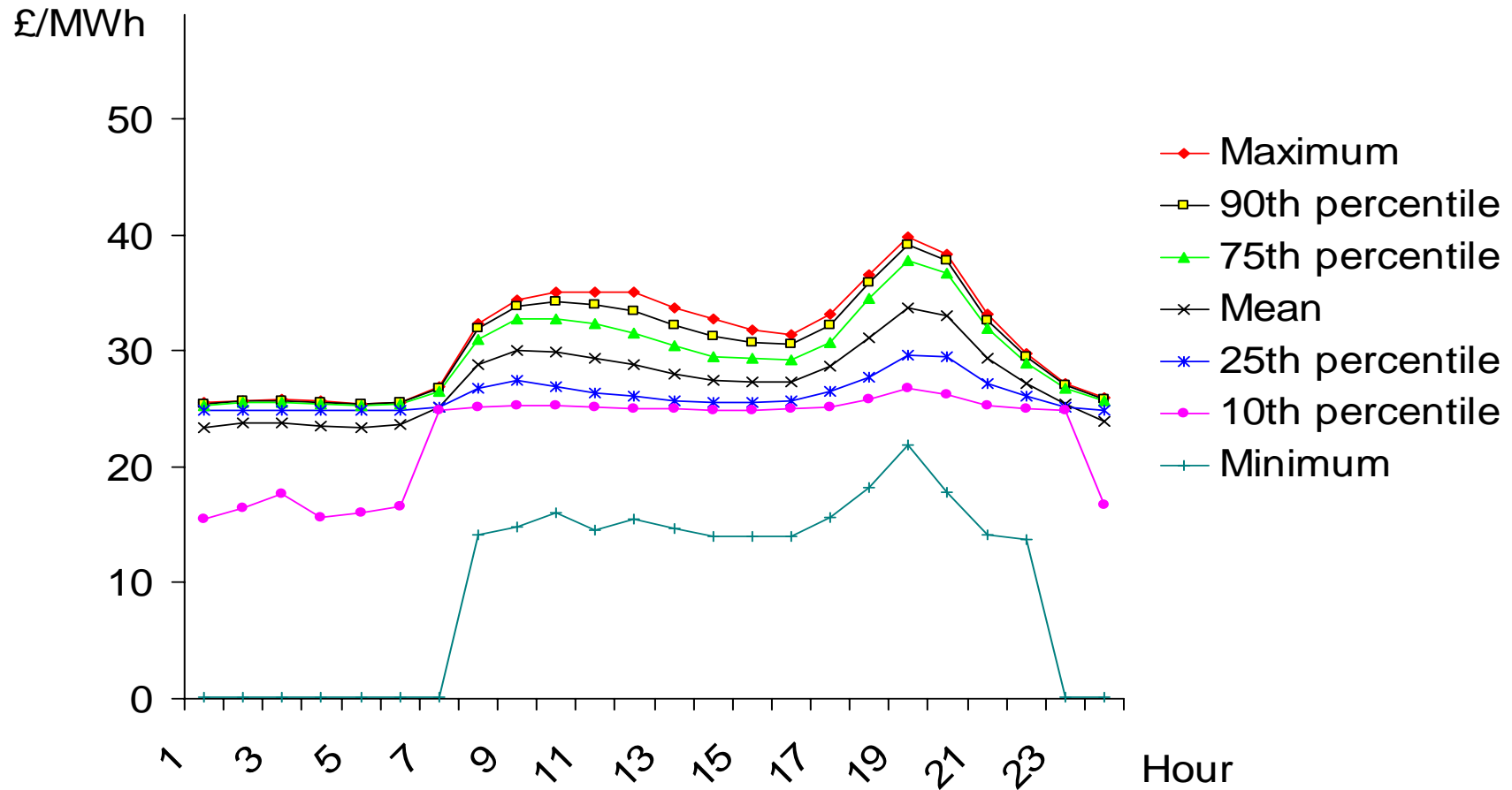


Price variation due to wind - 6 strategic firms





Price variation due to wind - 6 strategic firms



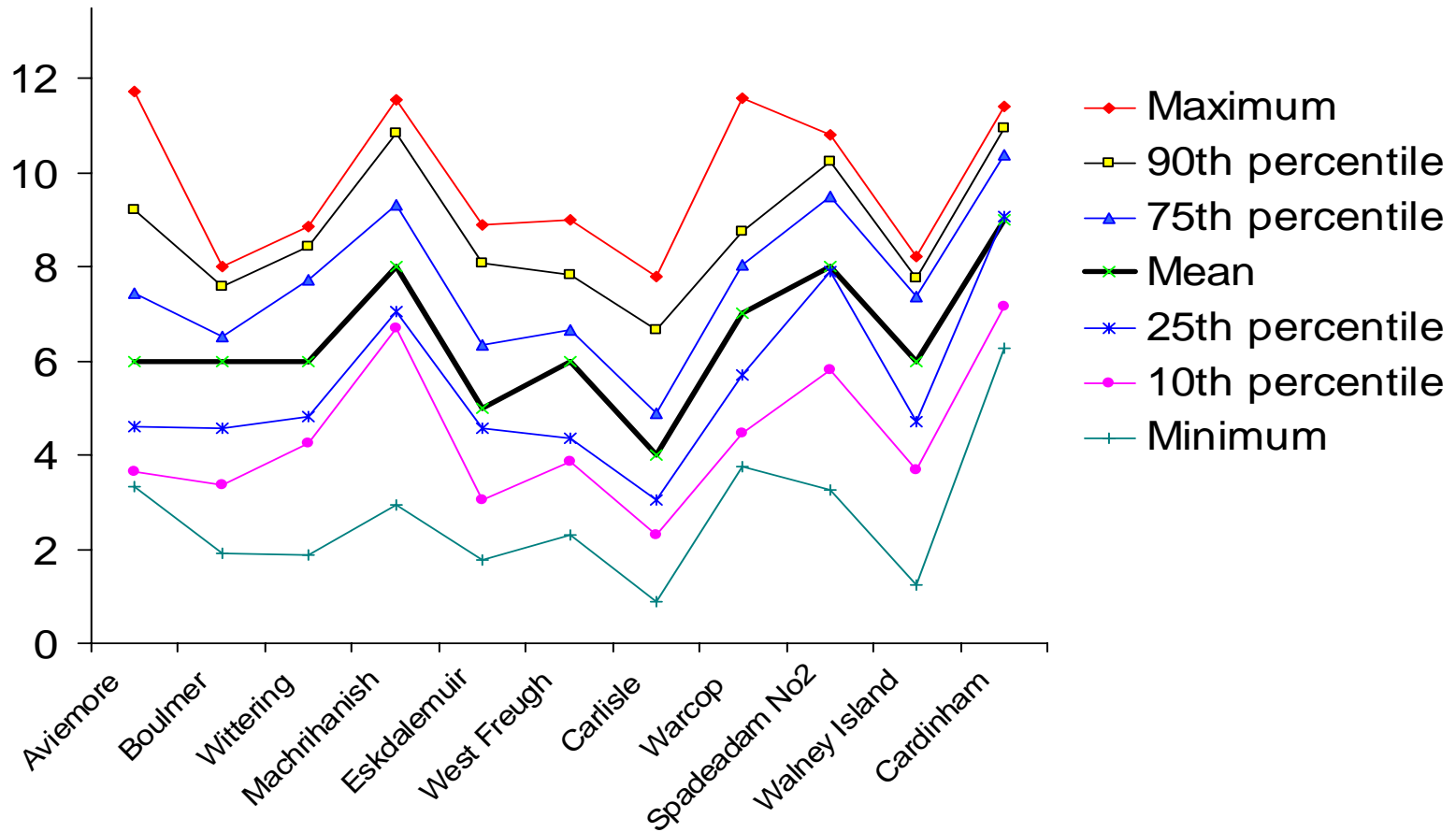
Do hourly variations matter?

- Generators make long-term investment decisions
- Will short-term variability deter them?
- Calculate monthly revenues for each year of wind observations
 - Assumes demand pattern repeated every day



Revenue variation due to wind - 6 strategic firms

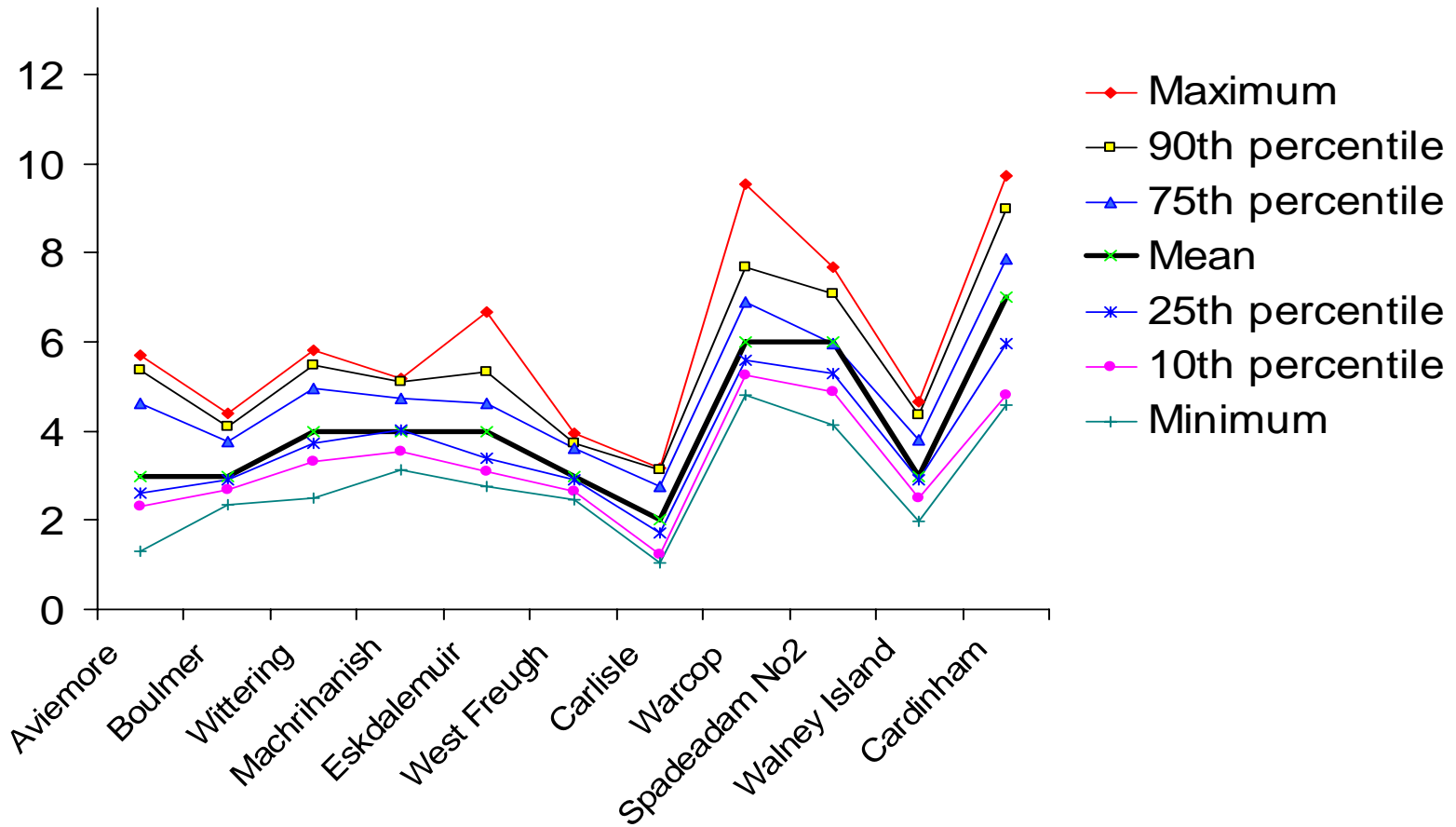
£/kW-month





Revenue variation due to wind - 6 strategic firms

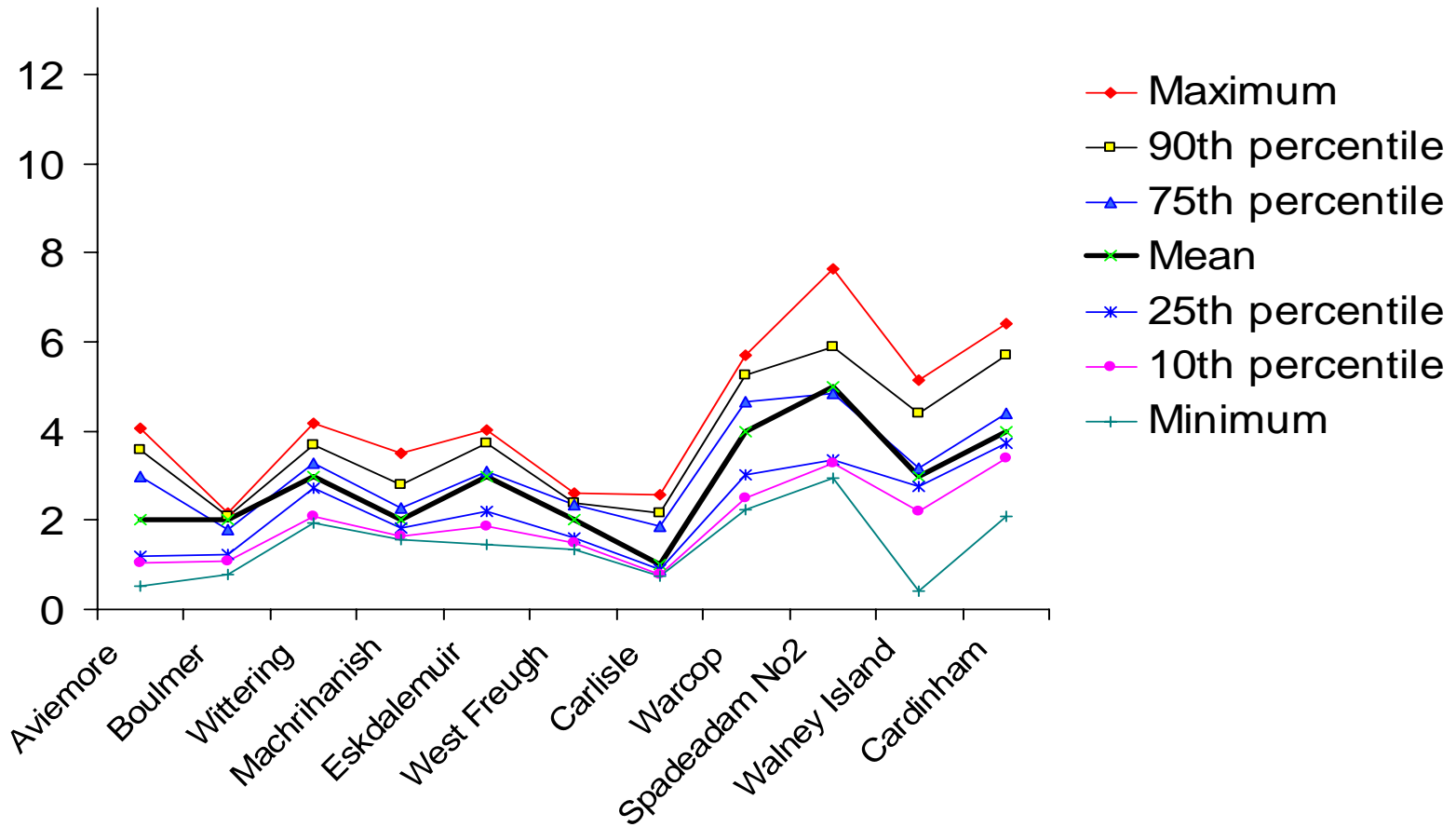
£/kW-month





Revenue variation due to wind - 6 strategic firms

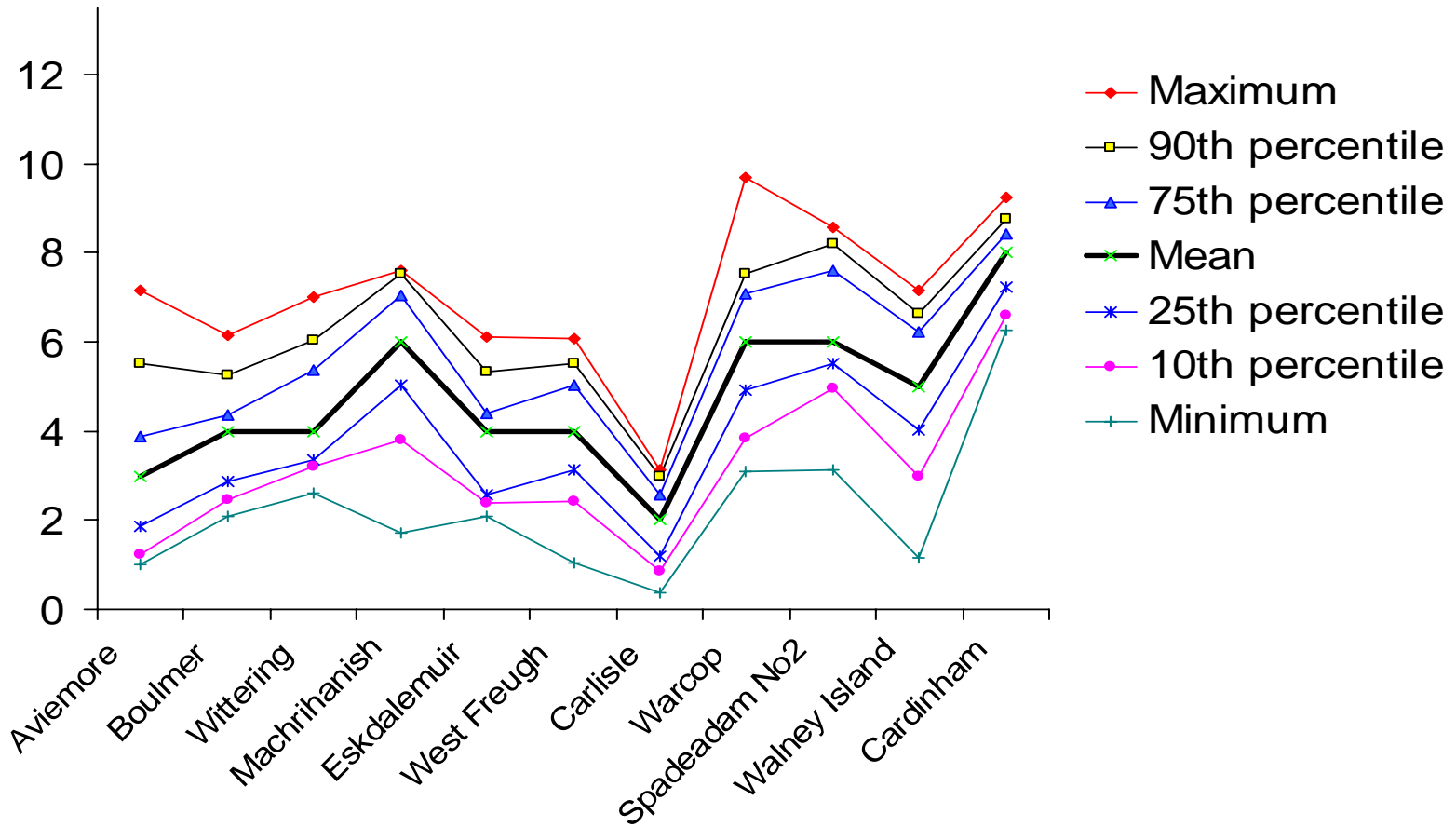
£/kW-month





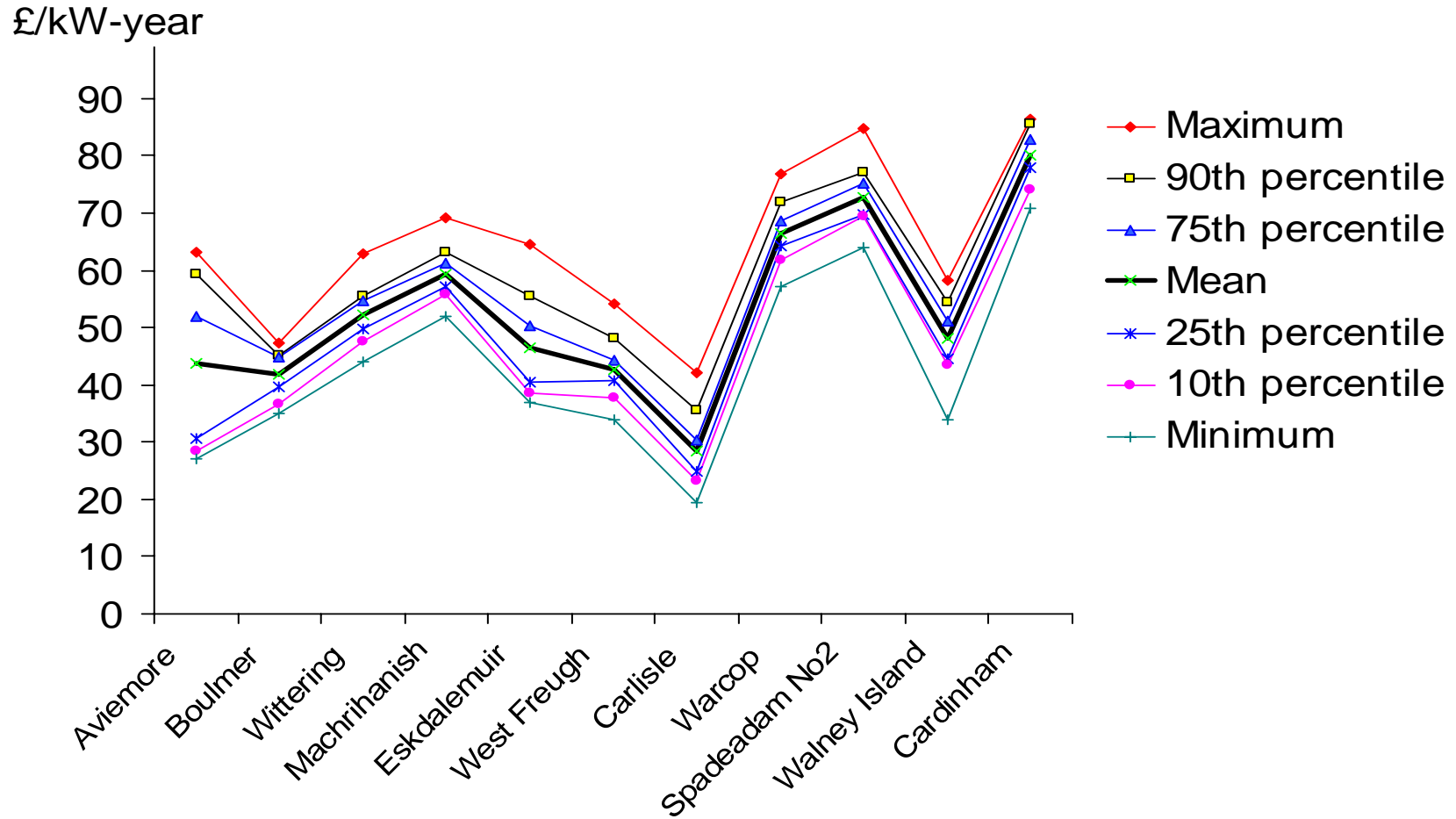
Revenue variation due to wind - 6 strategic firms

£/kW-month





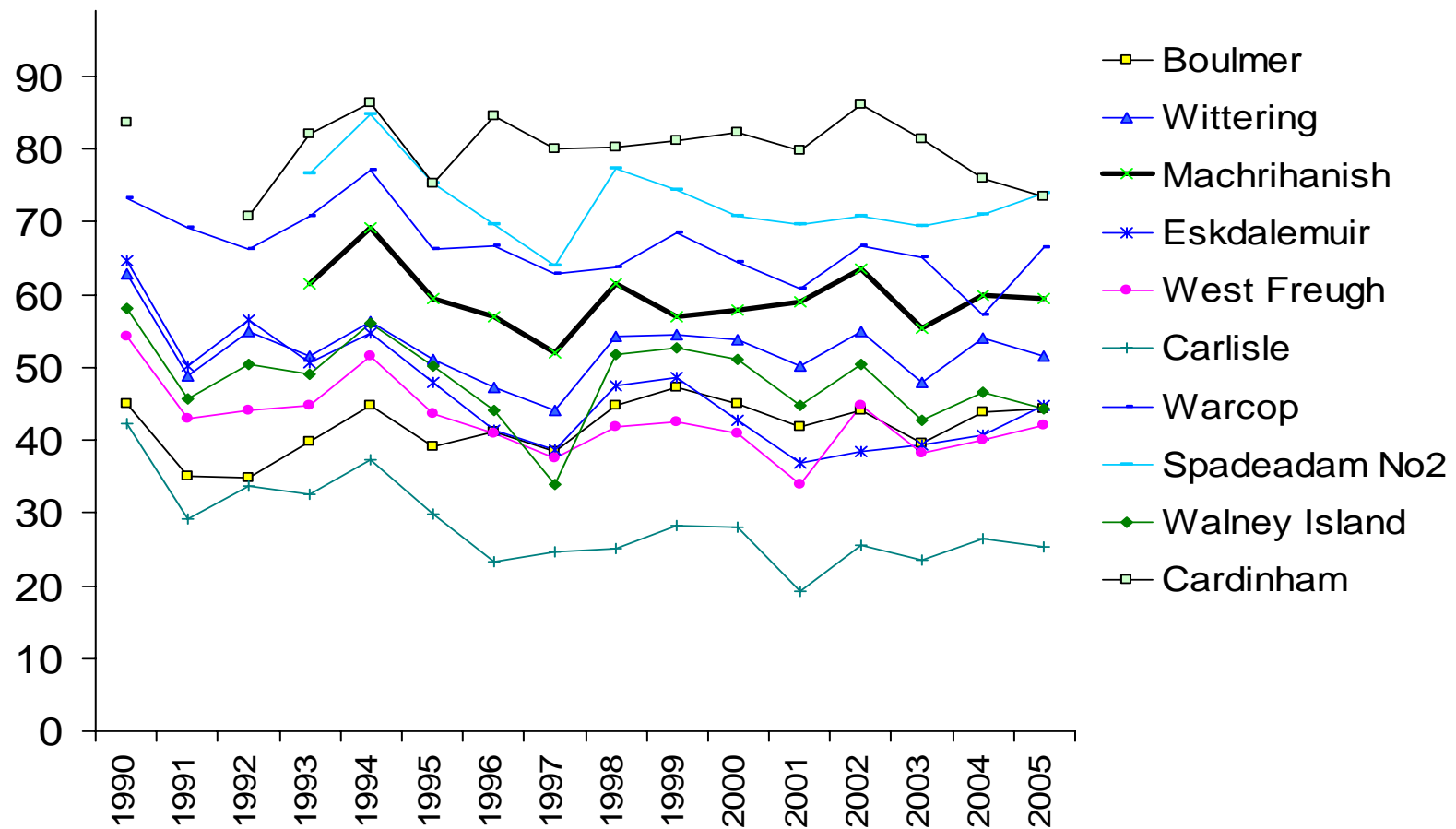
Revenue variation due to wind - 6 strategic firms





Revenue variation due to wind - 6 strategic firms

£/kW-year

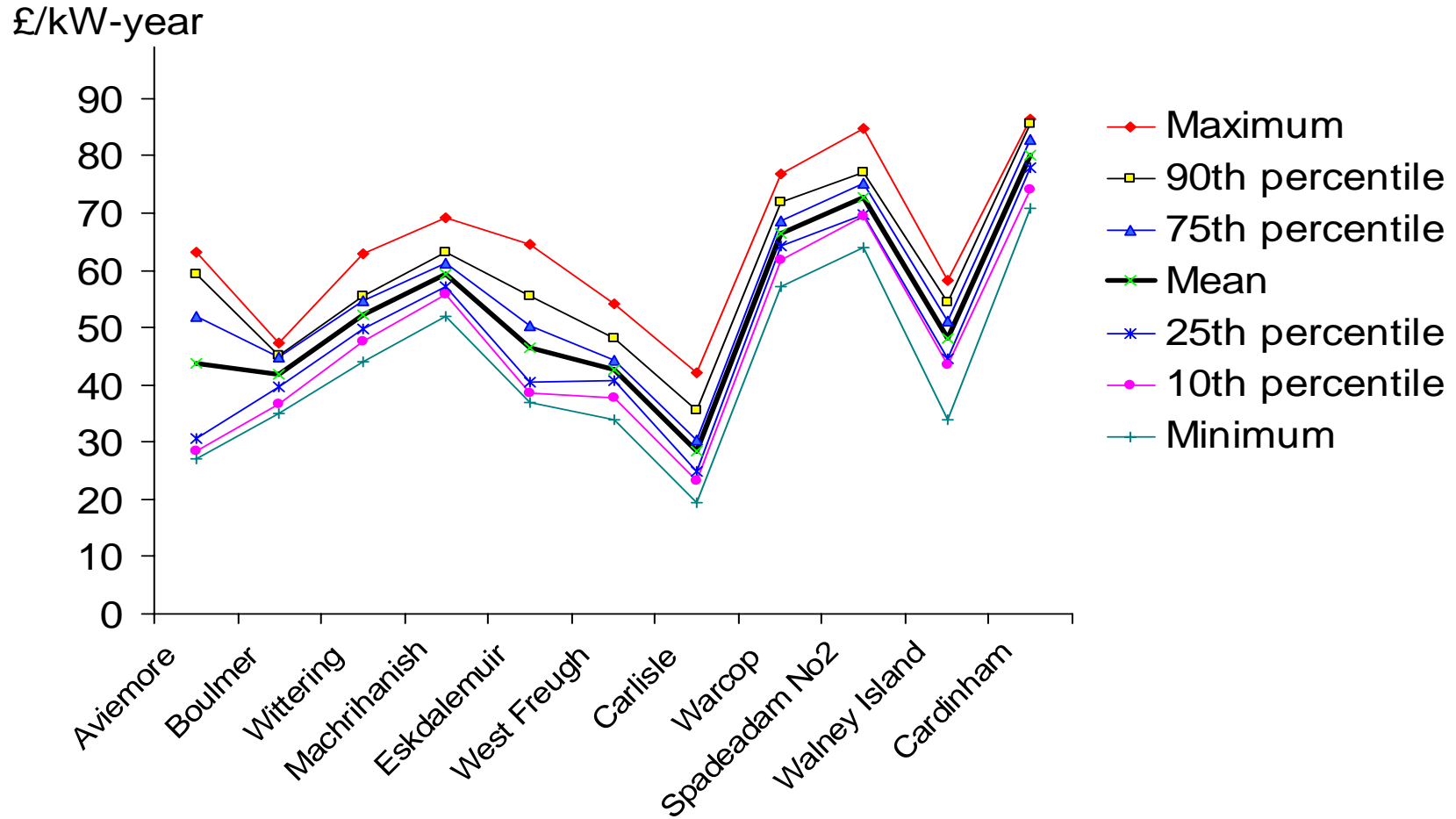


Fuel price risk

- Fuel prices may be volatile
- Wind costs not correlated with fuel prices
- Electricity prices are!
- For wind, revenue risk is profit risk
 - c.f. nuclear plant (Roques et al 2006)
- Draw fuel prices from a distribution based on DTI high, medium, low (Green, 2008)

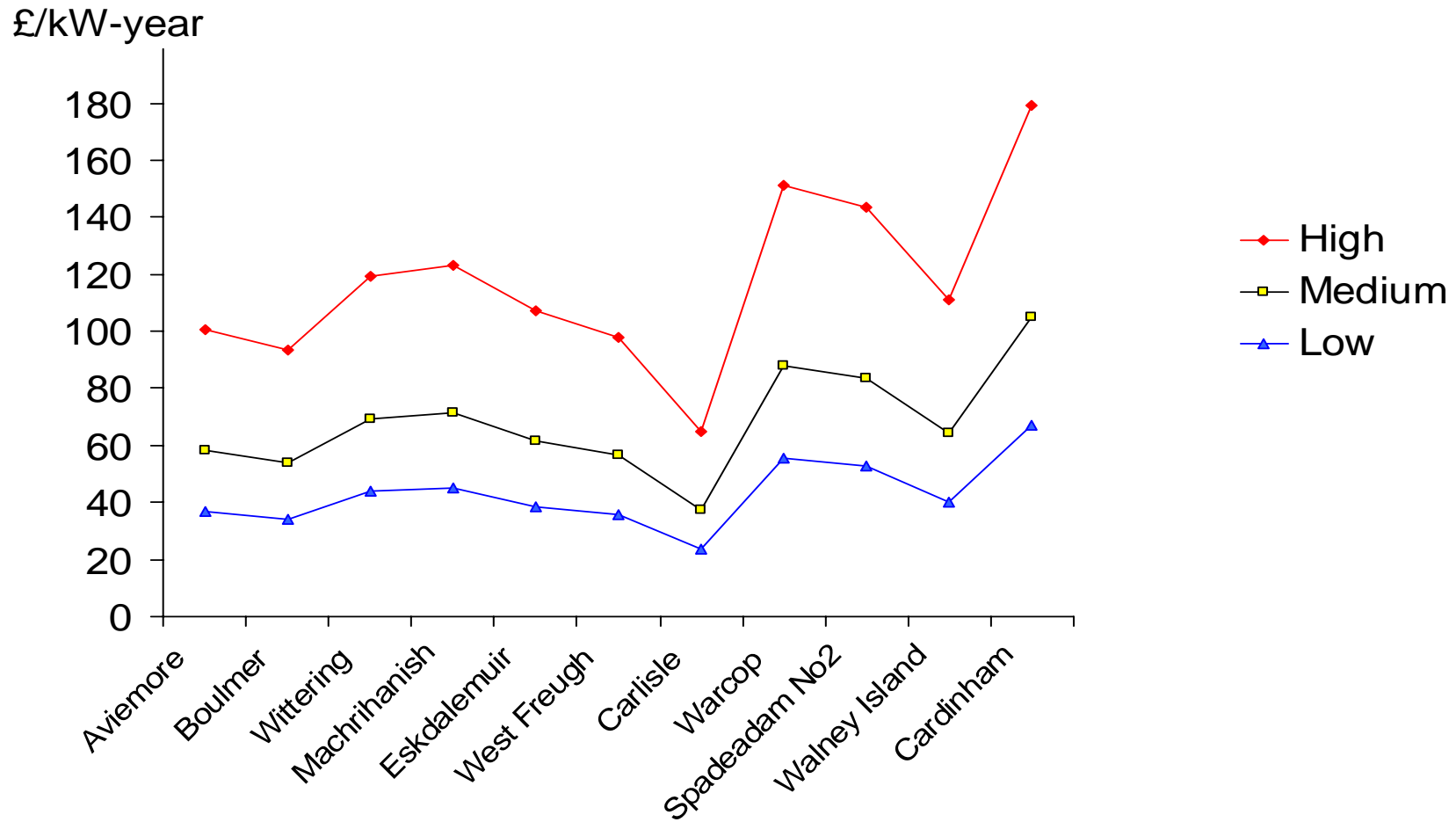


Revenue variation due to wind - 6 strategic firms





Revenue variation due to fuel - 6 strategic firms



Conclusions and future plans

- Prices are highly variable in response to wind
- So are monthly revenues
- Annual revenues much more stable
- Fuel price risk (should be) more of a concern
- Further work:
 - Optimal wind dispersion – trade-off between wind speed and correlation?
 - Consider cost-based thermal models
 - Implications for investment