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WELFARE EFFECT OF MARKET POWER IN STORAGE

Olayinka Williams and Richard Green

Energy Storage

- **Energy storage devices can provide much needed flexibility**

- **Economic benefits of storage**
  - Delay transmission and distribution upgrades,
  - Balancing services
  - Congestion relief
  - Reduce the cost of electricity generation
  - Integration of renewables

- **Storage usage**
  - Maximize social welfare (socially optimal operation)
  - Maximize Profits (strategic operation)

Energy Storage

- **Strategic operation of Storage**
  - Price spread manipulation
  - Starting and shutting off Generators
  - Welfare transfers/losses

- **Interaction with strategic generators**
  - Generator market power mitigation
  - Collusion

Start Costs

- **Fluctuation in demand and renewables**
  - Generator start
  - Generator shut down

- **Start Cost**
  - Fuel consumption necessary before generation

- **Start costs must be recovered**
  - Rolled into marginal cost (United Kingdom)
  - Presented with bid (Nodal system)

Literature

- **Market power and energy market**
  - Green and Newbery (1992), Borenstein and Bushnell (1999)
- **Market power and hydro**
  - Bushnell (2003), Kelman et al (2003), Mathiesen et al (2013)
- **Market power and Storage**
  - Sioshansi et al (2010), Schill and Kemfert (2011), Sioshansi (2014)

Objectives

- What welfare effects will strategic operation of storage have in the presence of competitive generators?
- What welfare effects will storage have in the presence of strategic generators?

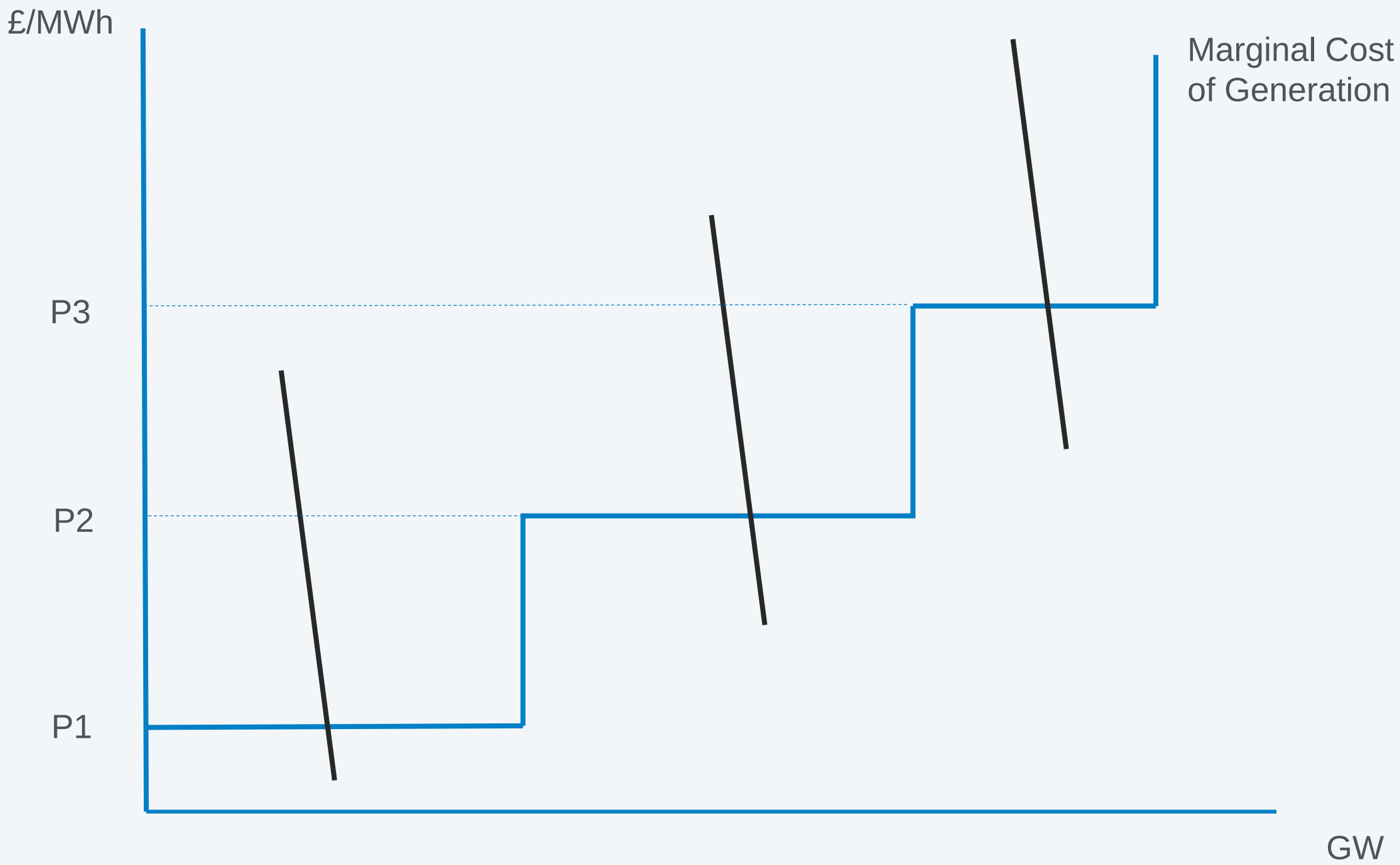
General Approach

- **Simulation of non-linear program**
  - **GAMS 24.7**

- **The use of sample days**
  - Obtained by clustering (see Green et al, 2014)

- **Merit Order stack with start heuristics**
  - Staffell and Green (2016)

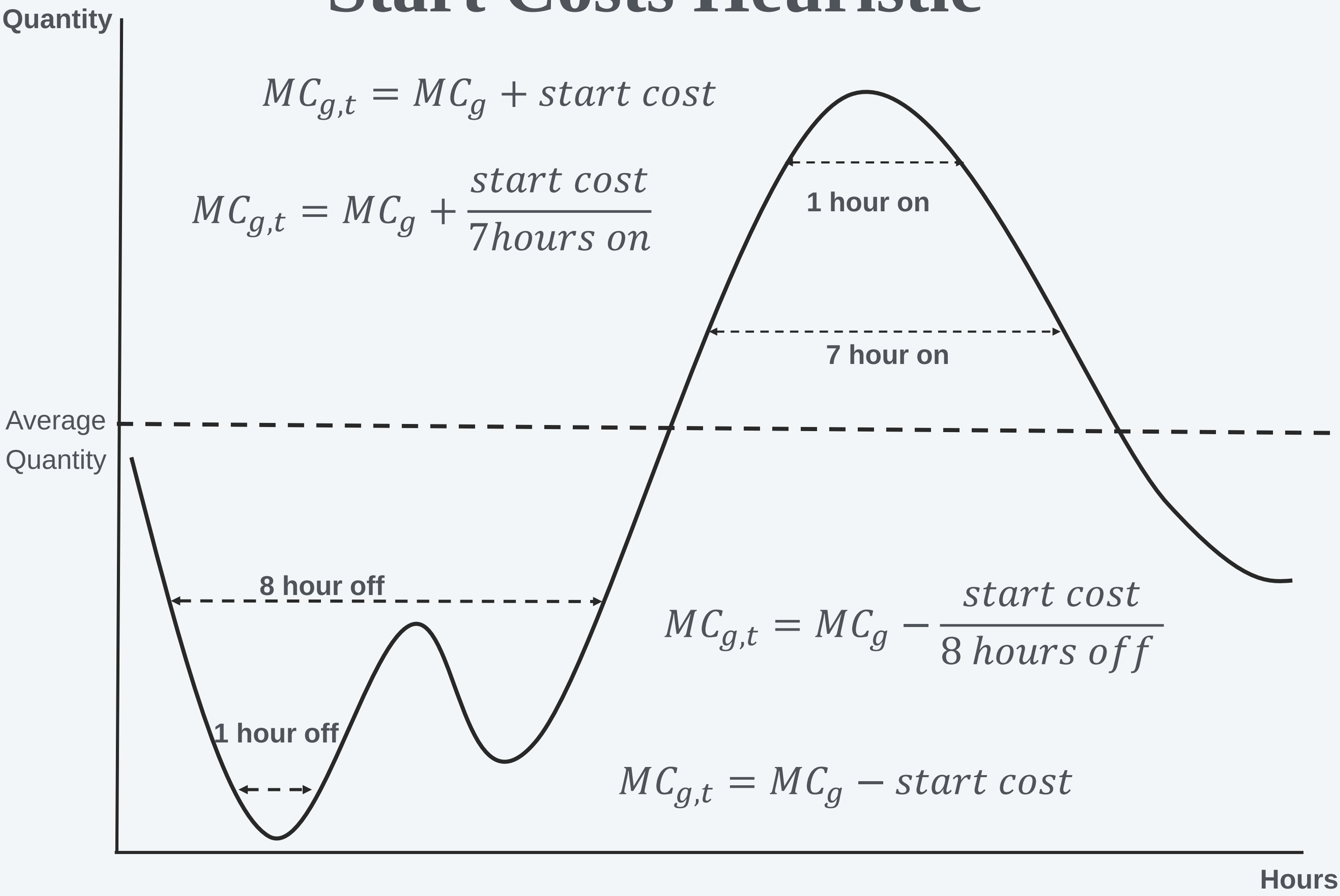
The Merit Order Stack



Start Costs Heuristic

$$MC_{g,t} = MC_g + start\ cost$$

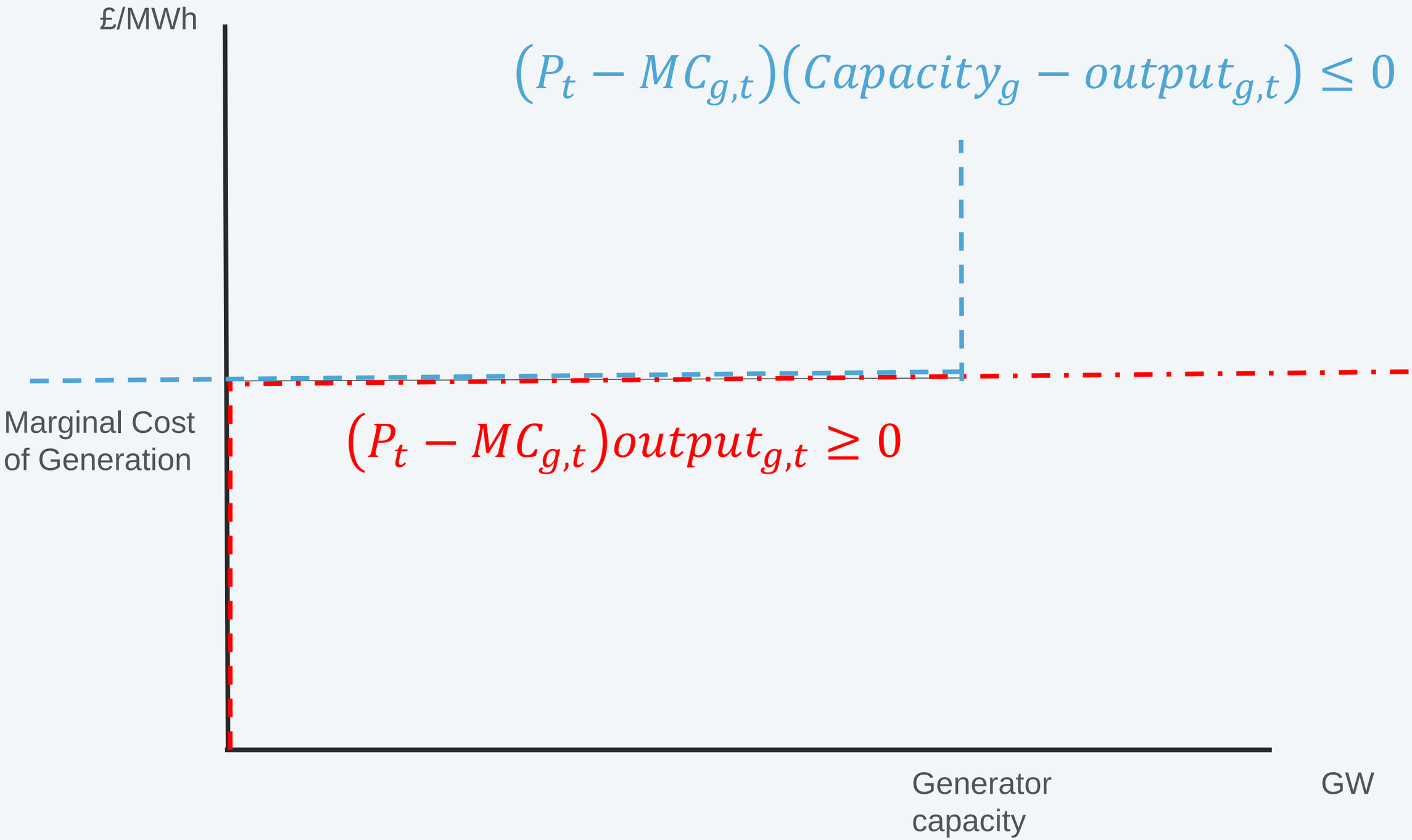
$$MC_{g,t} = MC_g + \frac{start\ cost}{7 hours\ on}$$



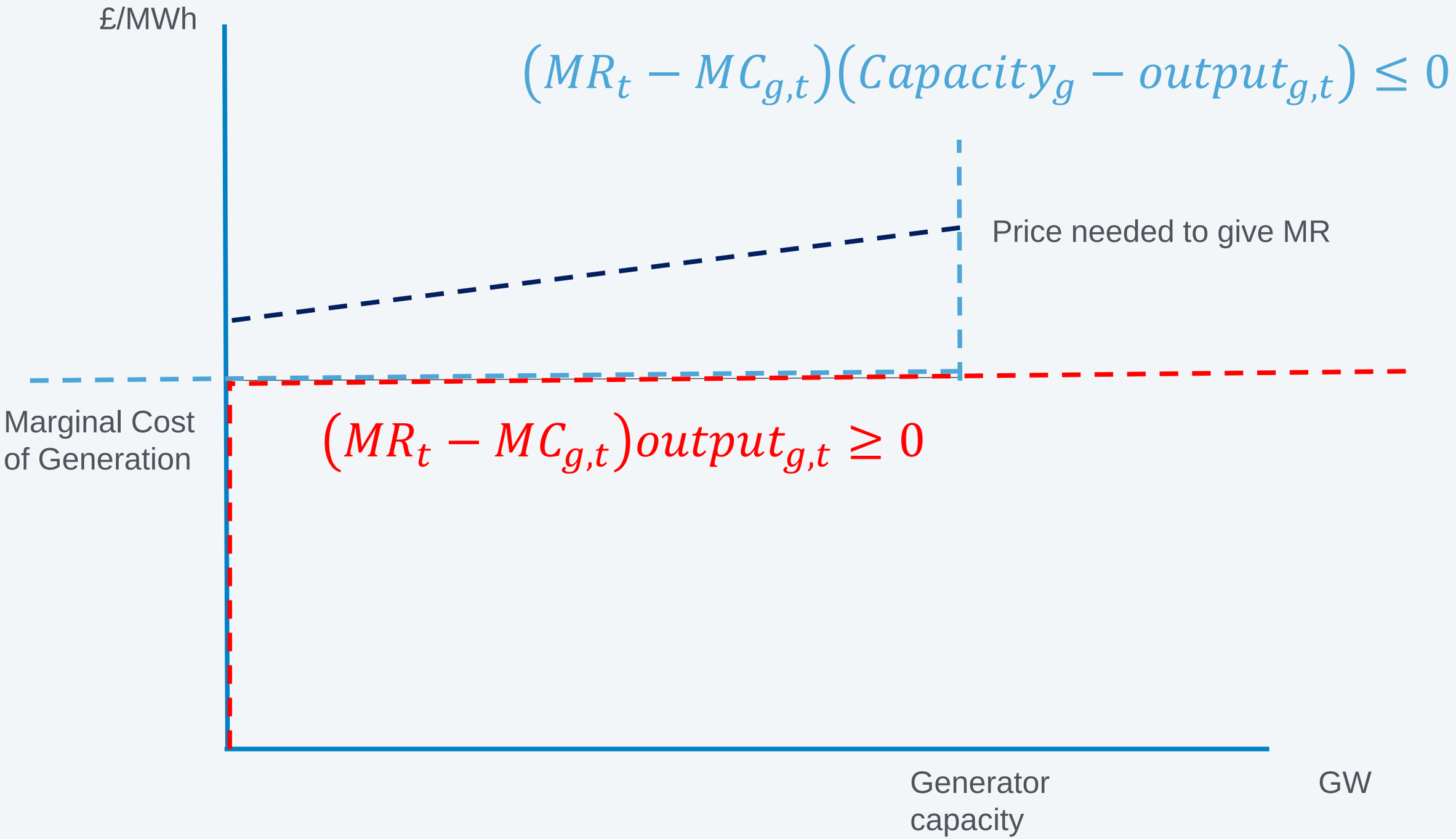
$$MC_{g,t} = MC_g - \frac{start\ cost}{8\ hours\ off}$$

$$MC_{g,t} = MC_g - start\ cost$$

A Competitive Generator



A Strategic Generator



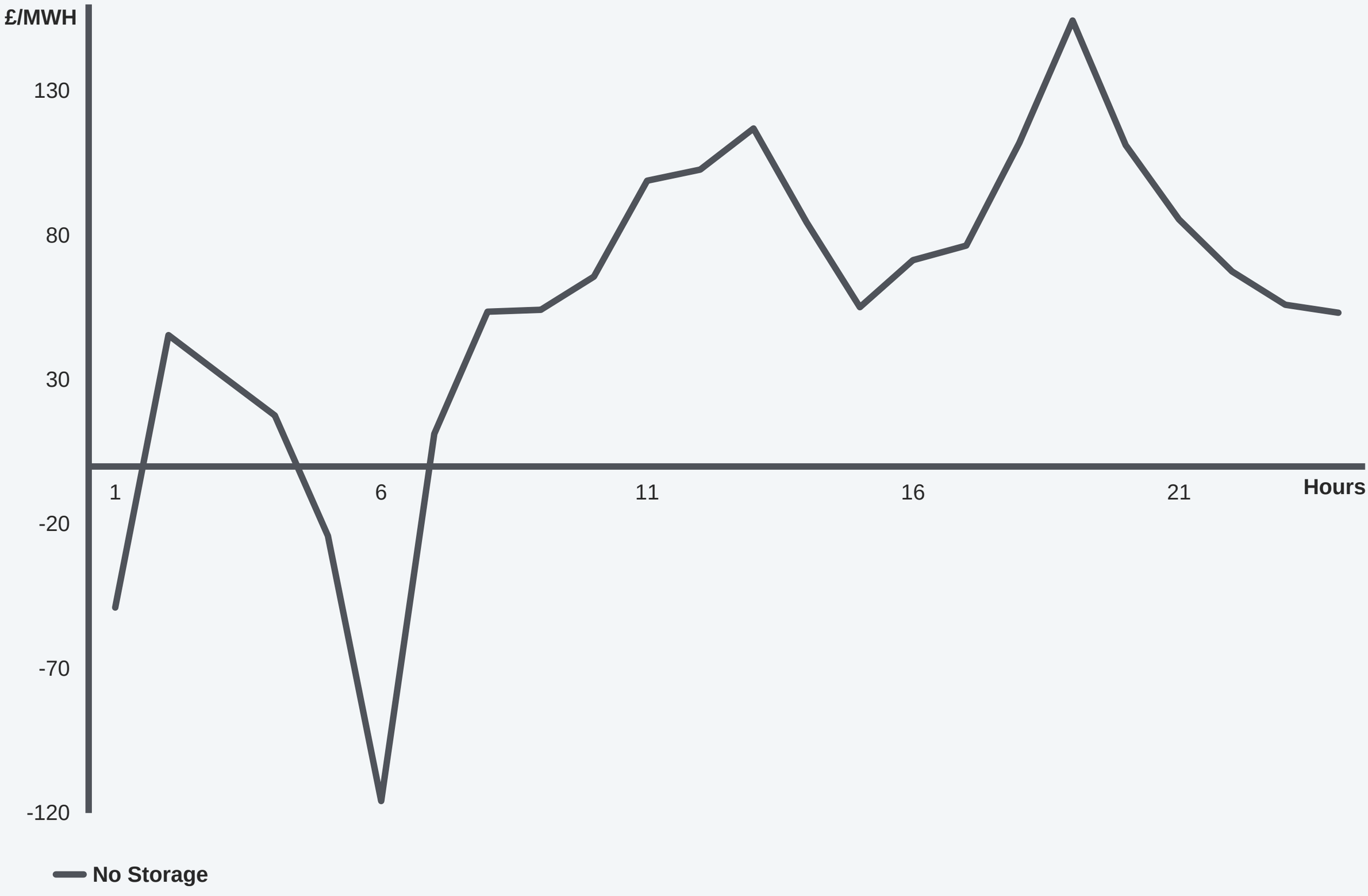
Data

- **Load Data**
  - –National Grid

- **Renewable load factors**
  - –*Weather data from NASA's MERRA database*
  - –Virtual wind farm (Pfenninger and Staffell (2016))

- **Generator Costs**
  - – Green and Staffell(2014)

Competitive Generation



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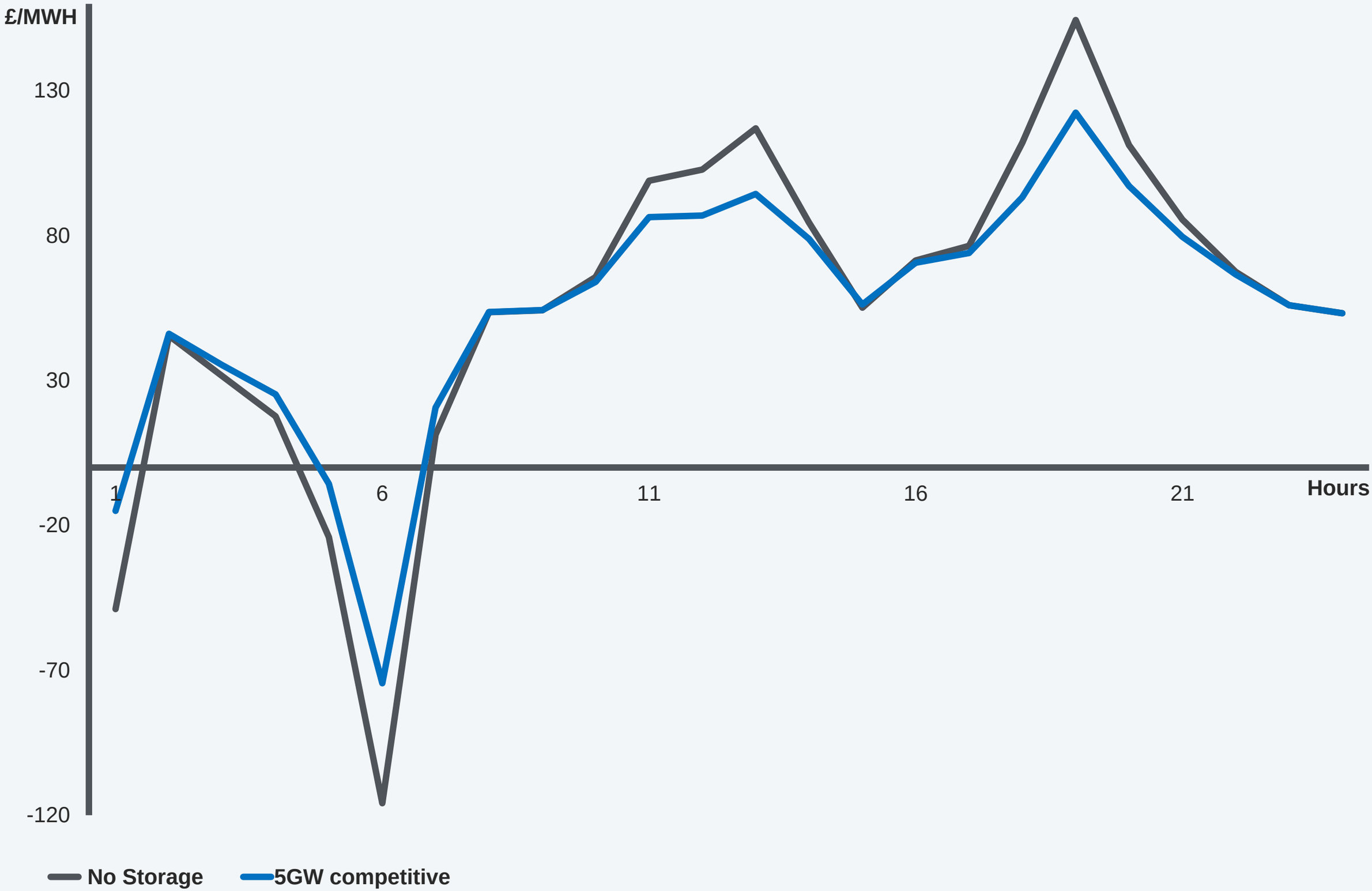

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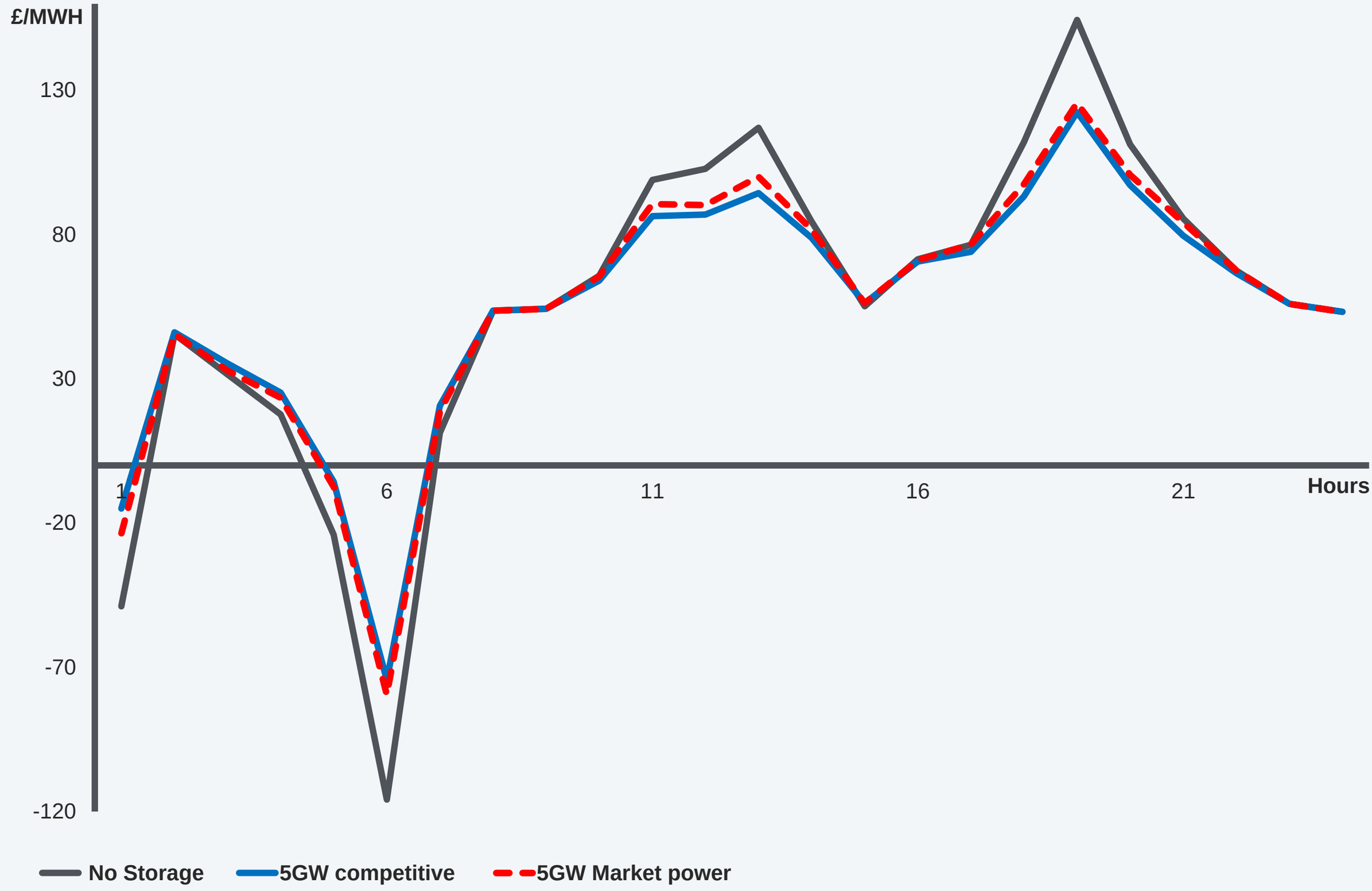

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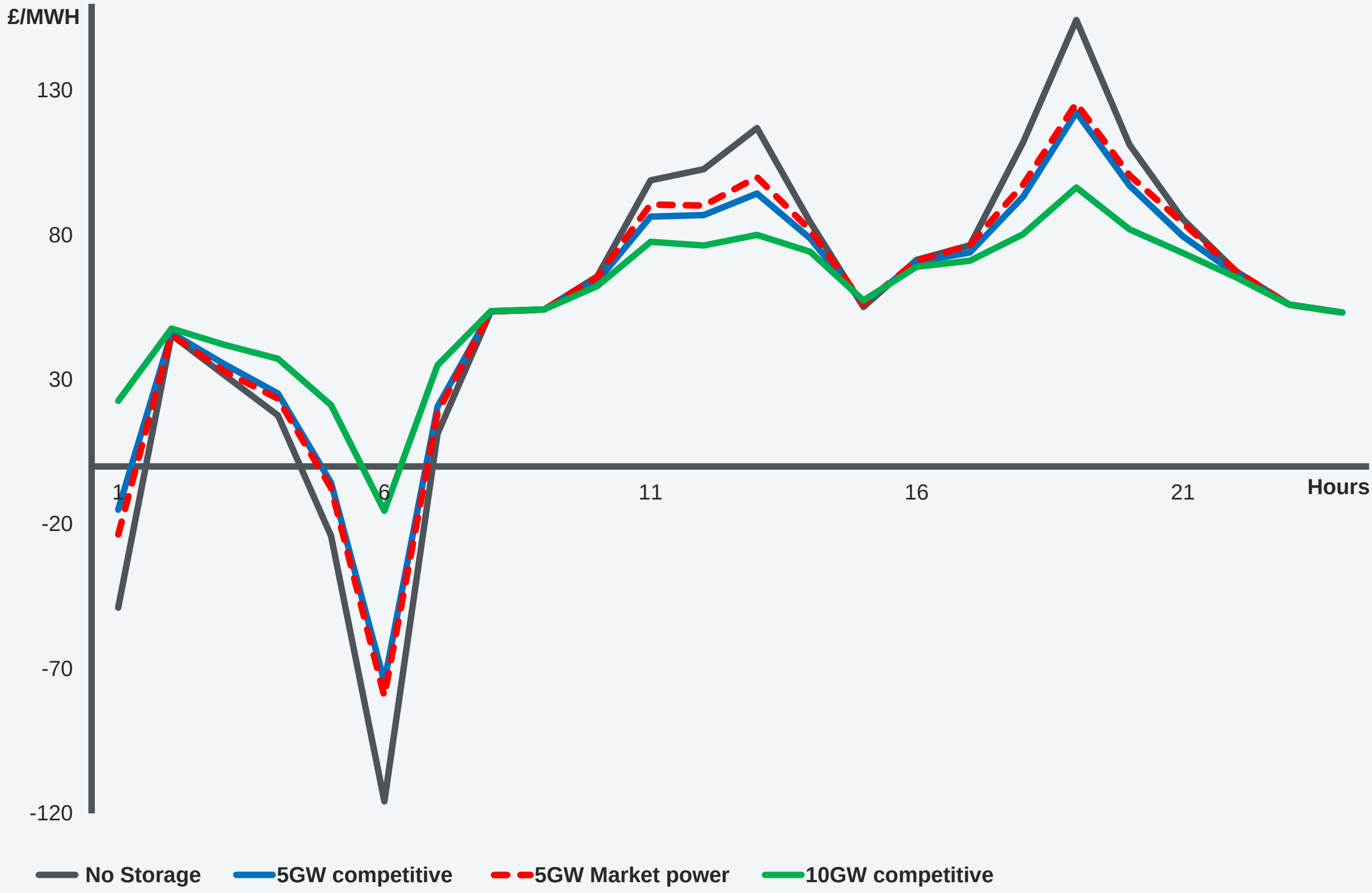
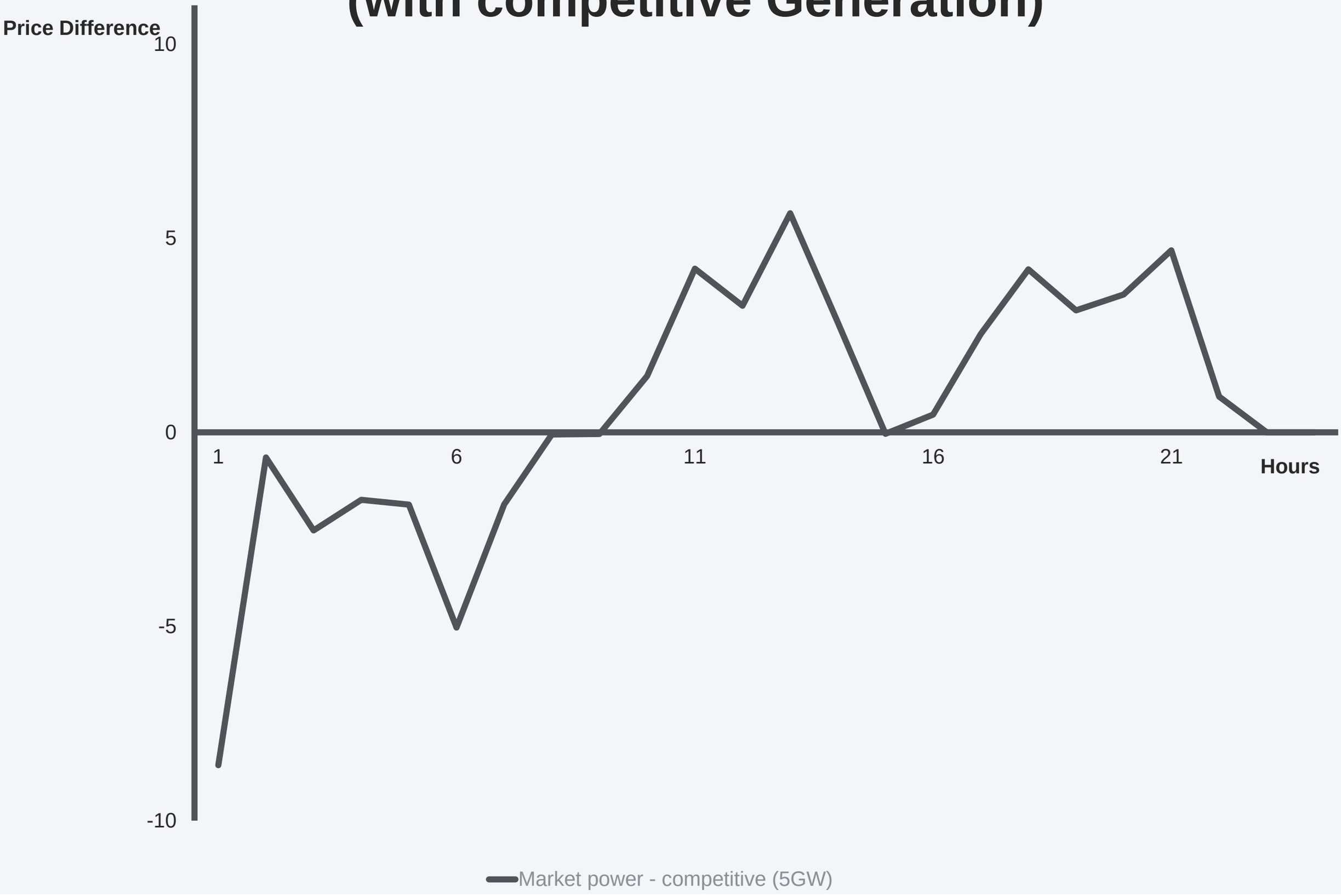


Competitive Generation

Impact of market power in storage (with competitive Generation)



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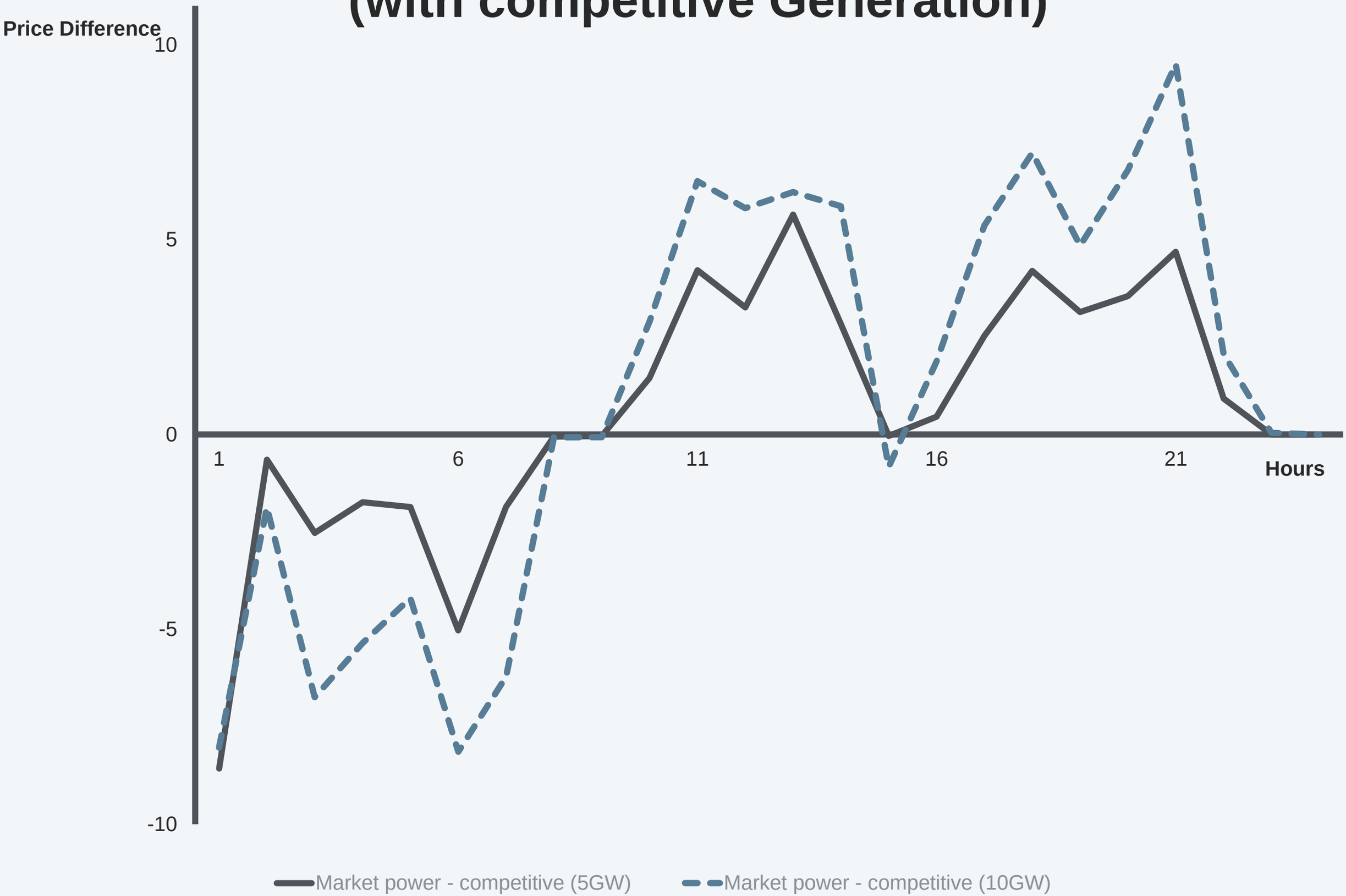

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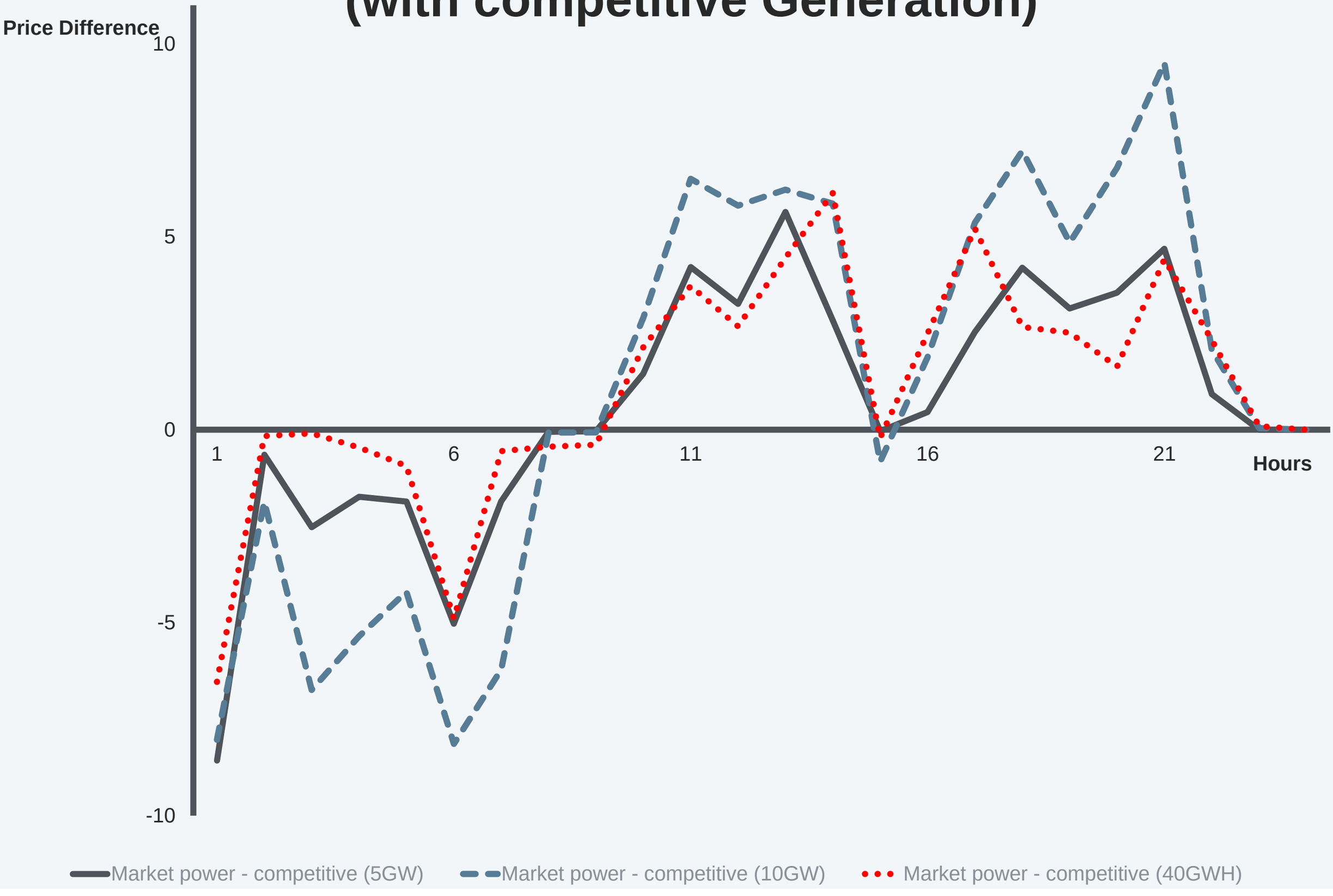
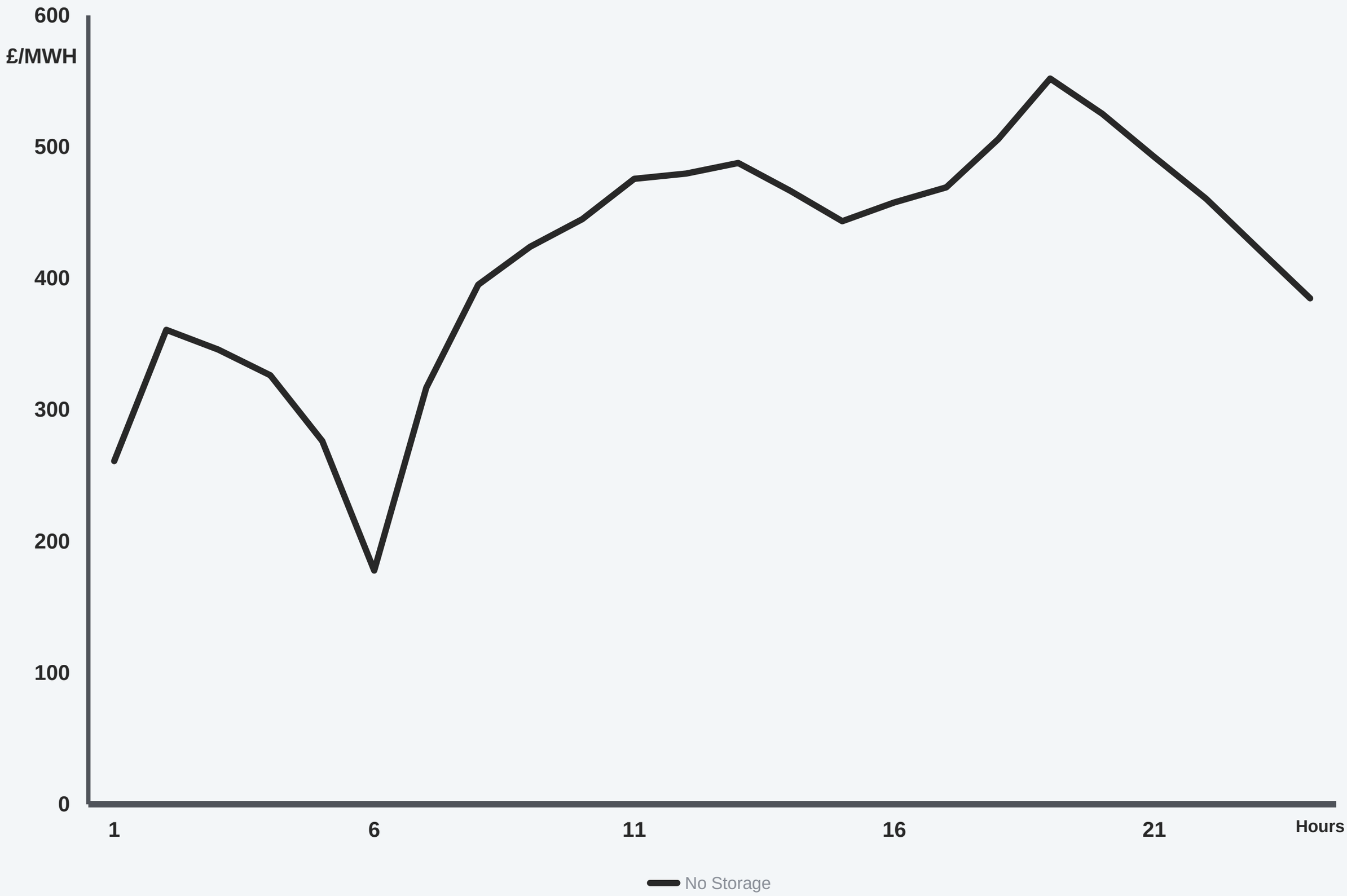


Strategic Generation



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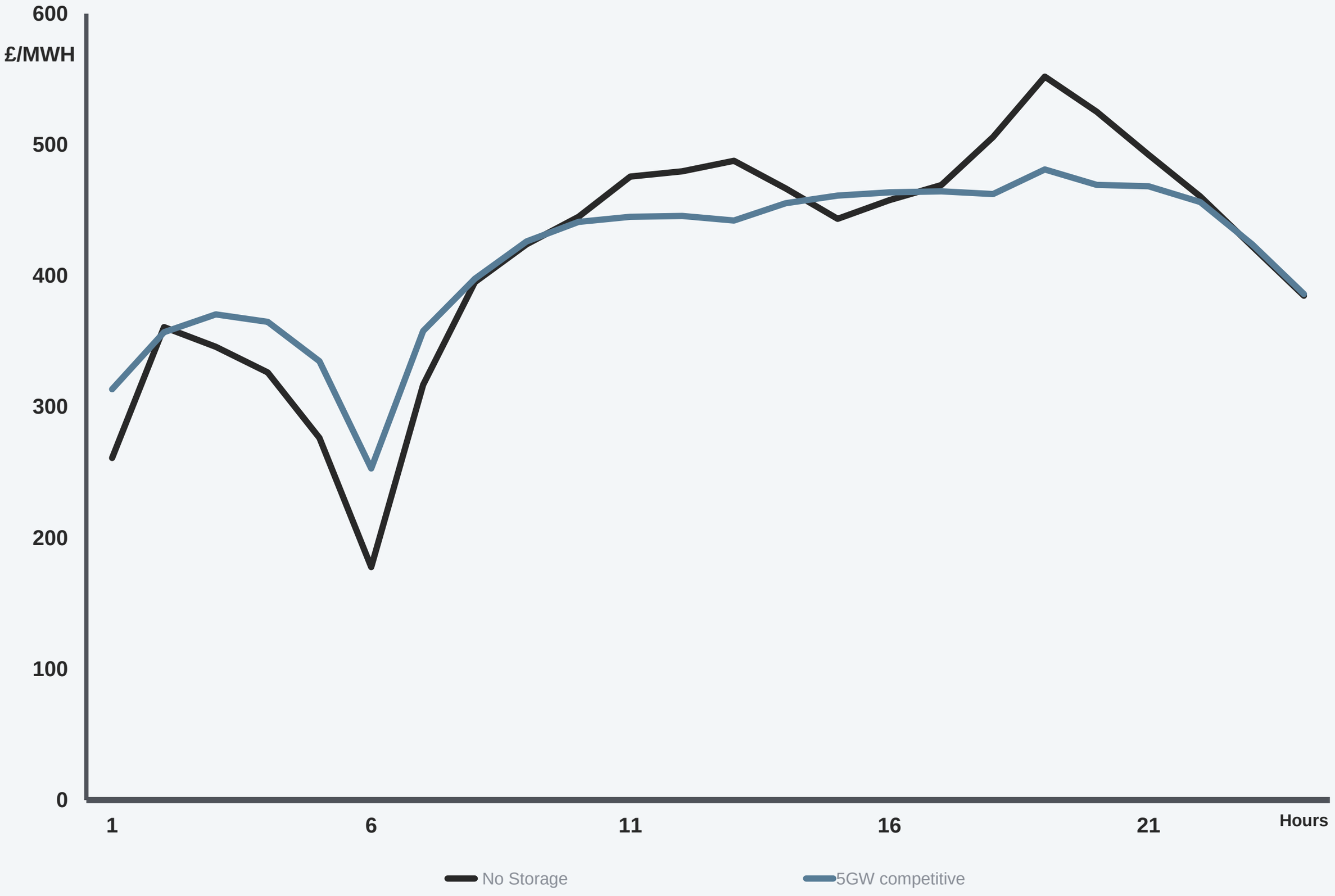

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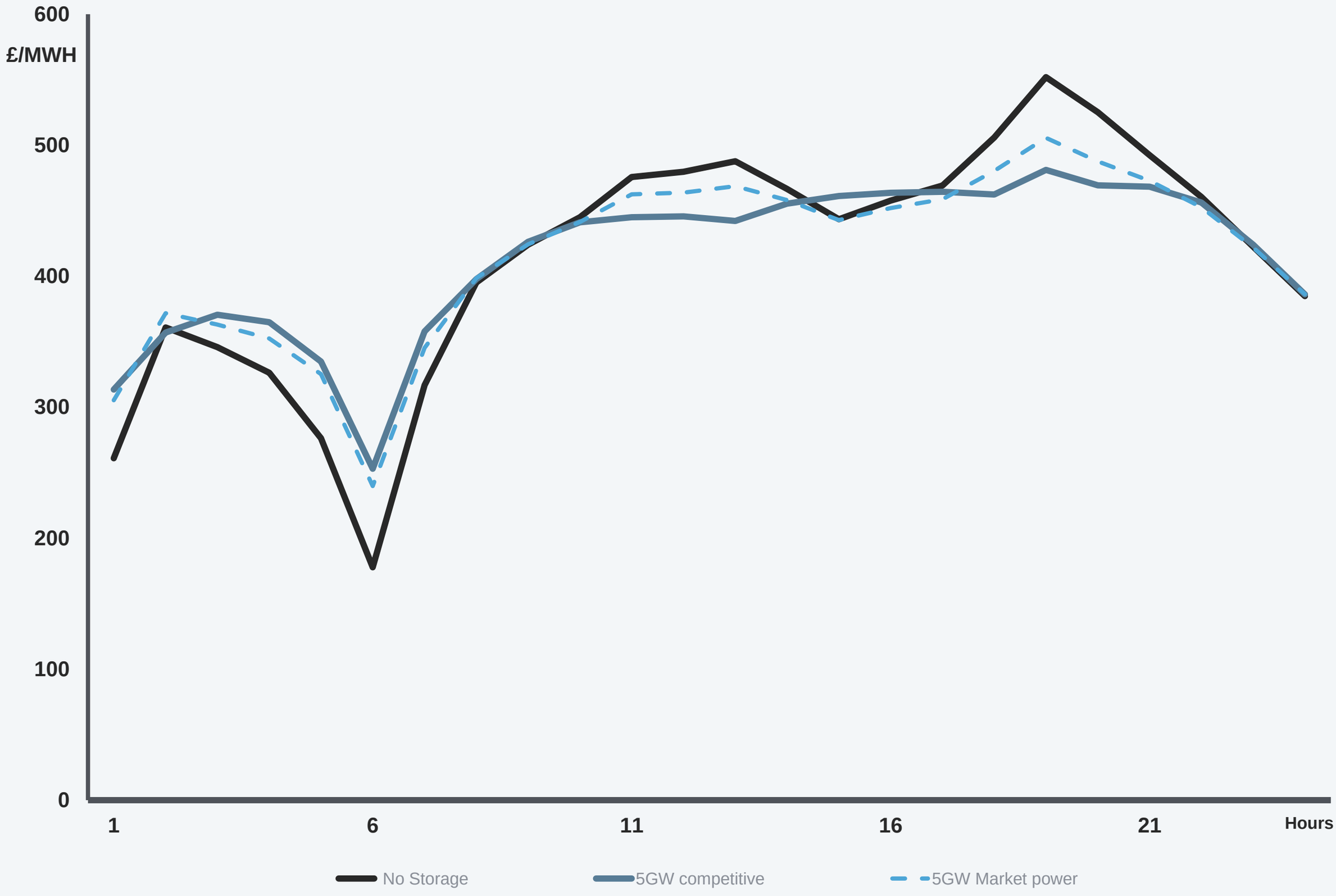

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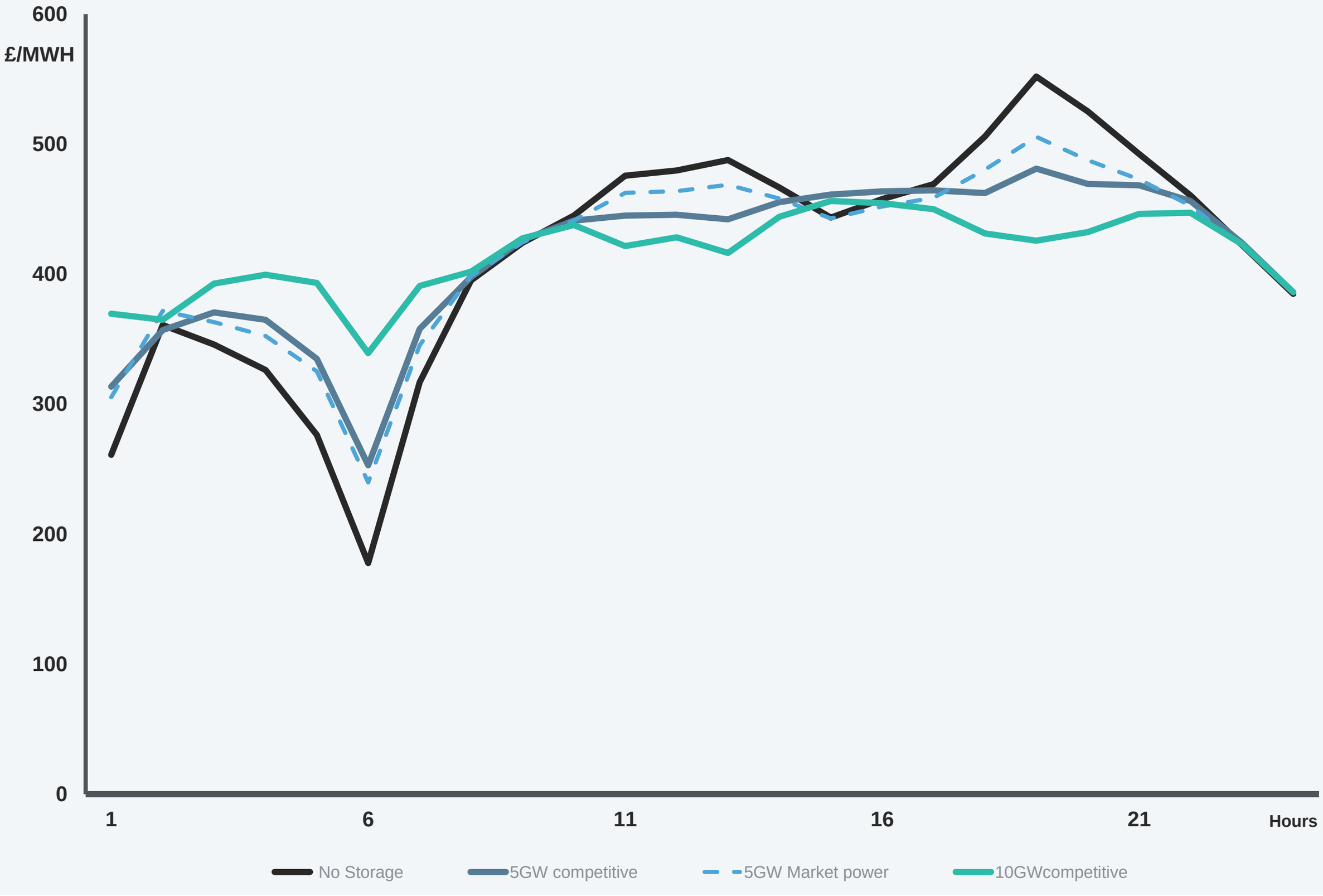
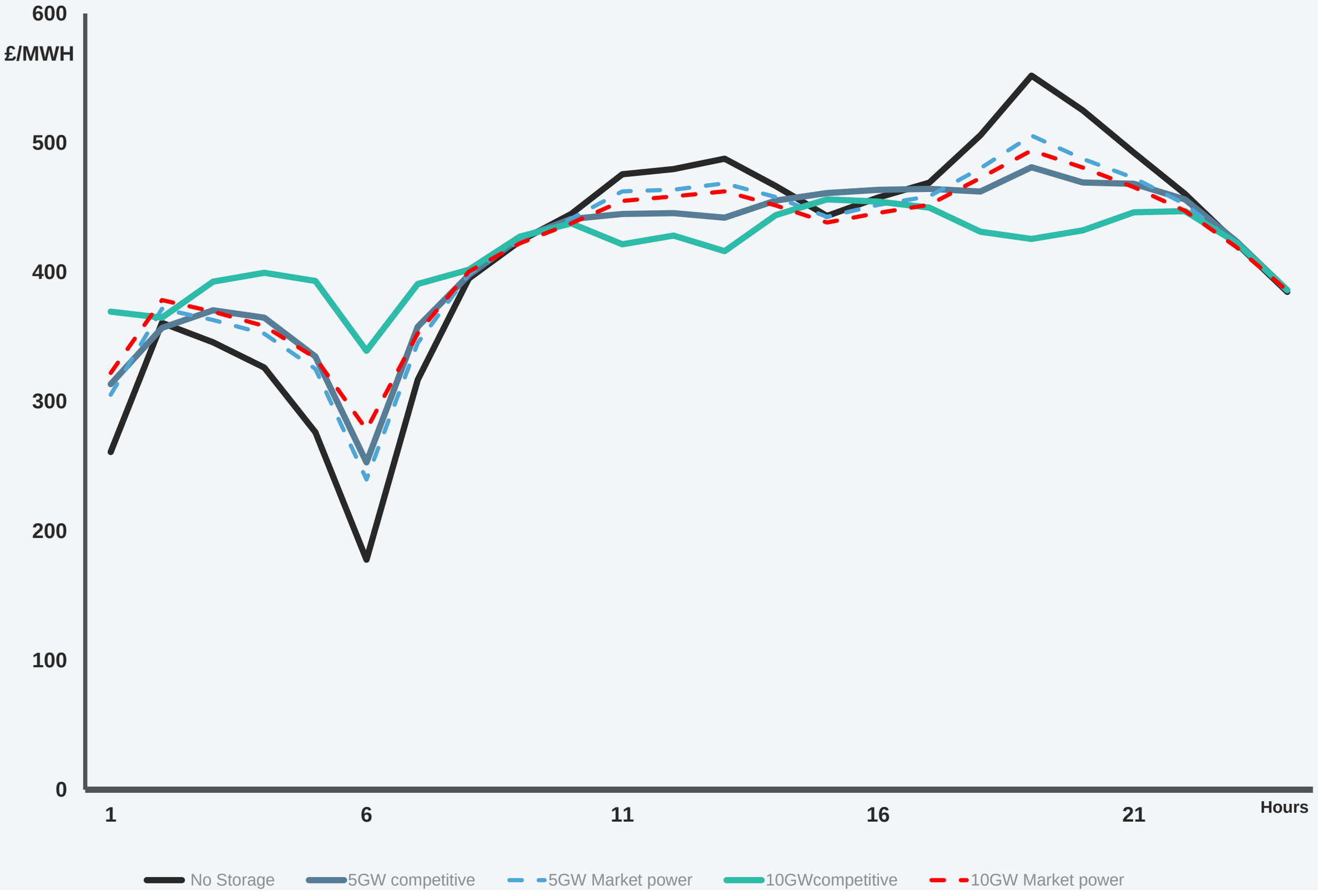
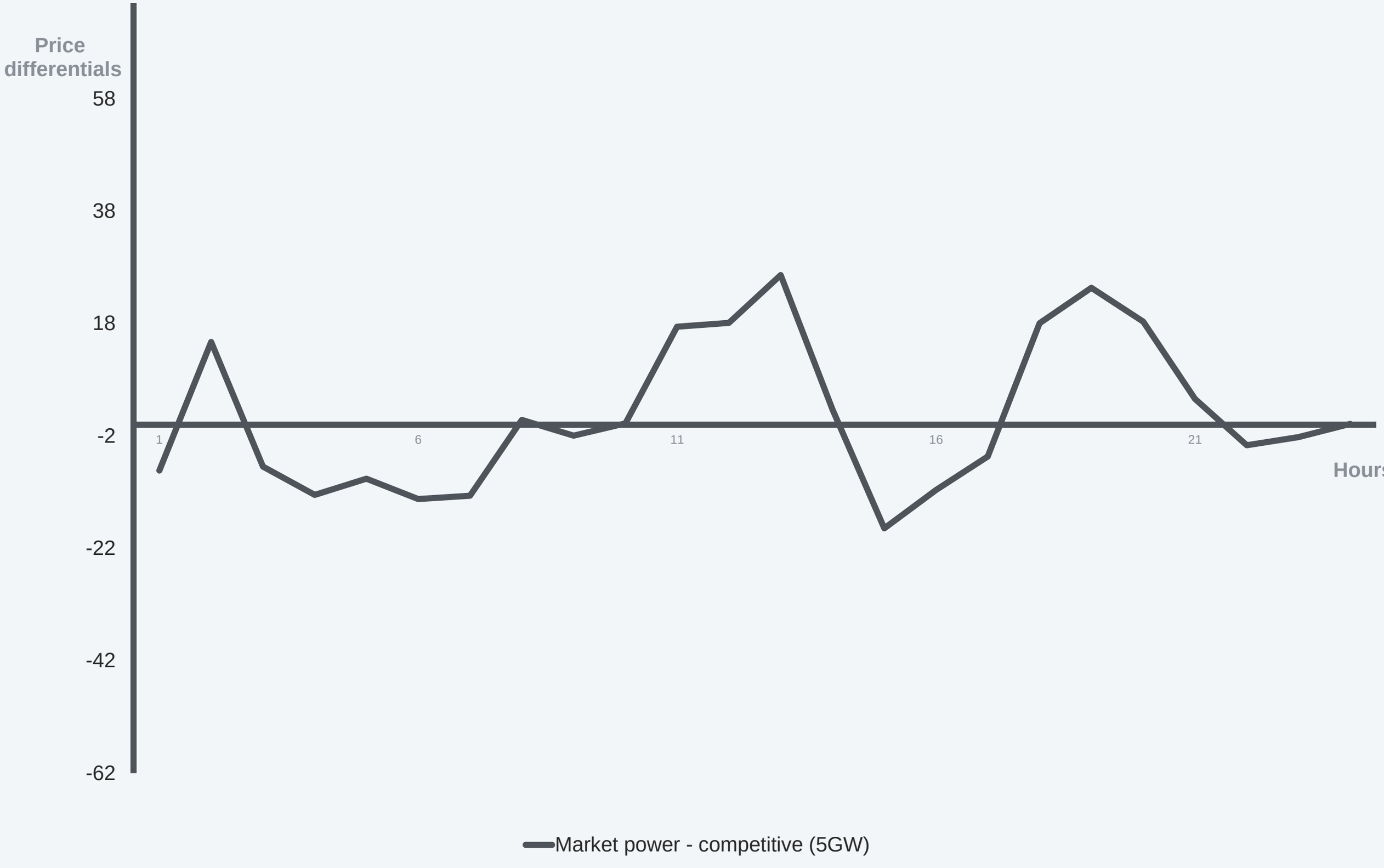


Strategic Generation



Price differential with Strategic Generation



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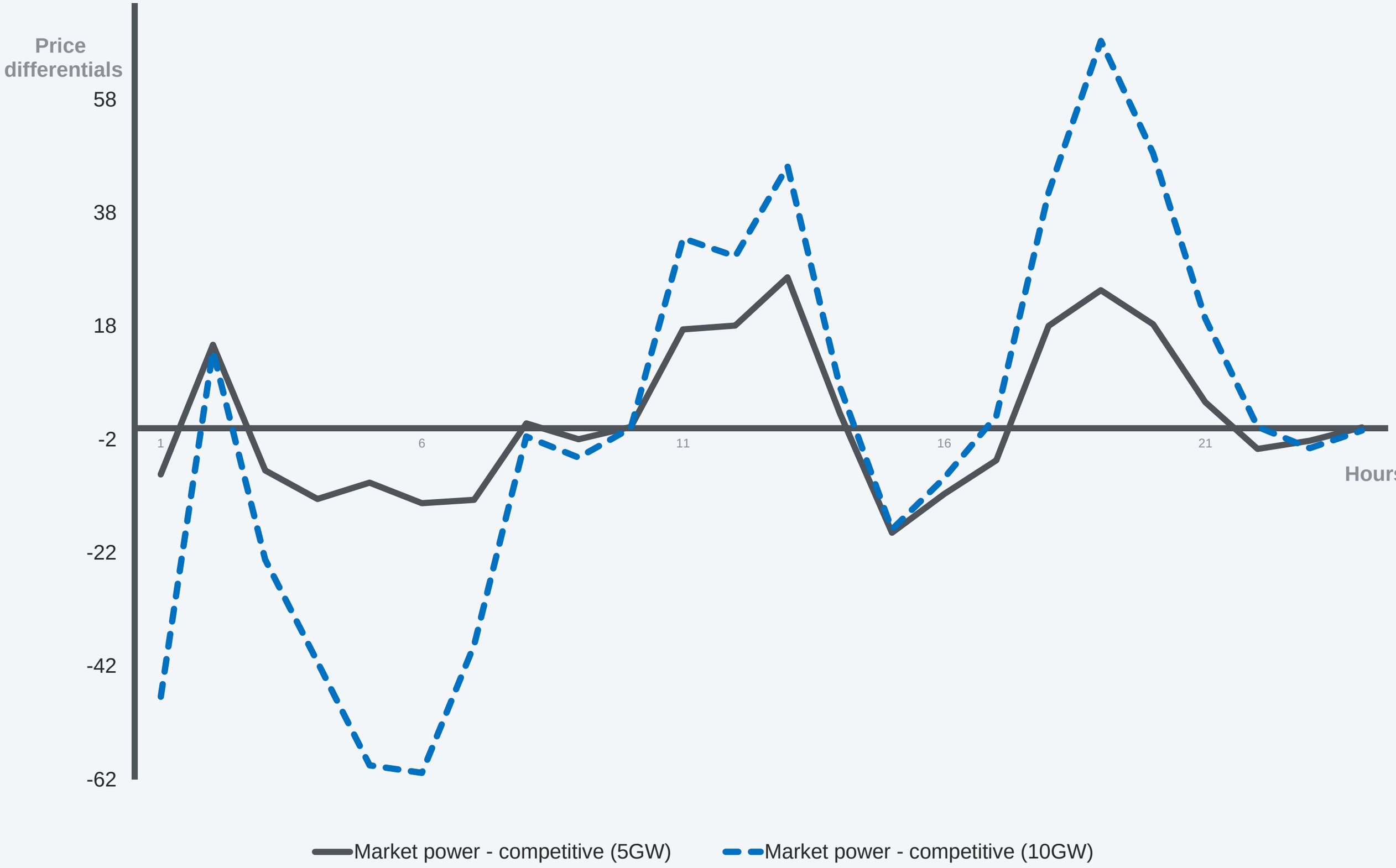

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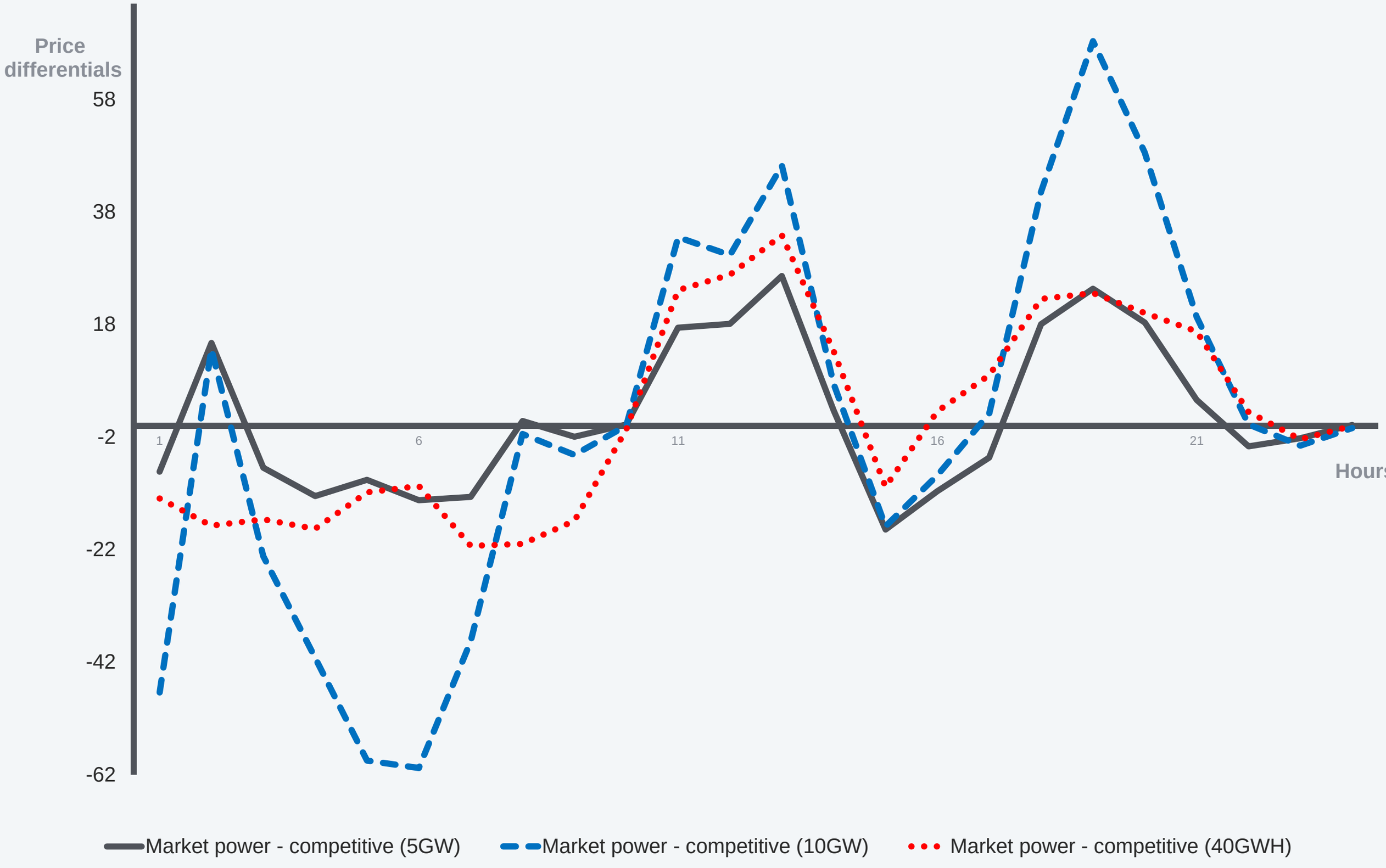

Welfare Effects (Competitive Generators)

Storage	Welfare (Welfare/Turnover)	Consumer Surplus (£/millions)	Generator profit (£/millions)	Storage Profit (£/millions)	Energy Discharged (GWH)
5GW, 20GWh	-0.04	-221	154	56	-45
10GW, 40GWh	-0.05	-429	225	203	-120
5GW, 40GWh	-0.06	-318	250	56	-75

Welfare Effects (Strategic Generators)

Storage	Welfare (Welfare/Turnover)	Consumer Surplus (£/millions)	Generator profit (£/millions)	Storage Profit (£/millions)	Energy Discharged (GWH)
5GW, 20GWh	-0.0005	-634	72.9	376.7	-2,211
10GW, 40GWh	0.0008	-1,018.5	-875.5	1,396.4	-6,475
5GW, 40GWh	- 0.0010	-847.9	197.5	430.5	-4,169

Concluding Remarks

- **Strategic operation has marginal effects on welfare/ turnover ratio.**
- **Higher power rating will amplify loses from strategic storage operation.**
- **Strategic generators can lose when storage is operated strategically.**
- **Socially optimal operation of a very large storage device might not be sustainable.**


ANY
QUESTIONS
?

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