

WELFARE EFFECT OF MARKET POWER IN STORAGE

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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)

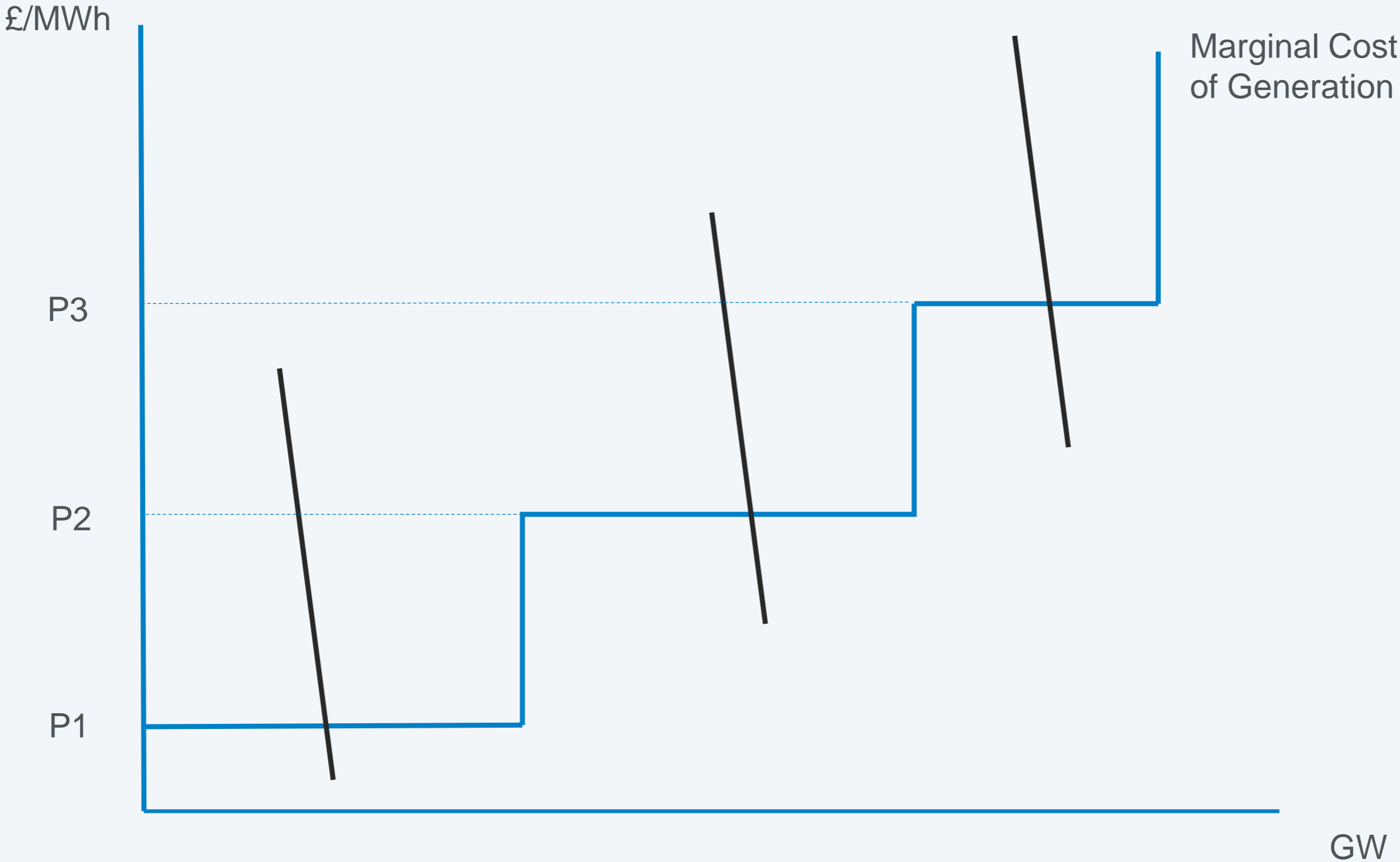
Objectives

- **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?**

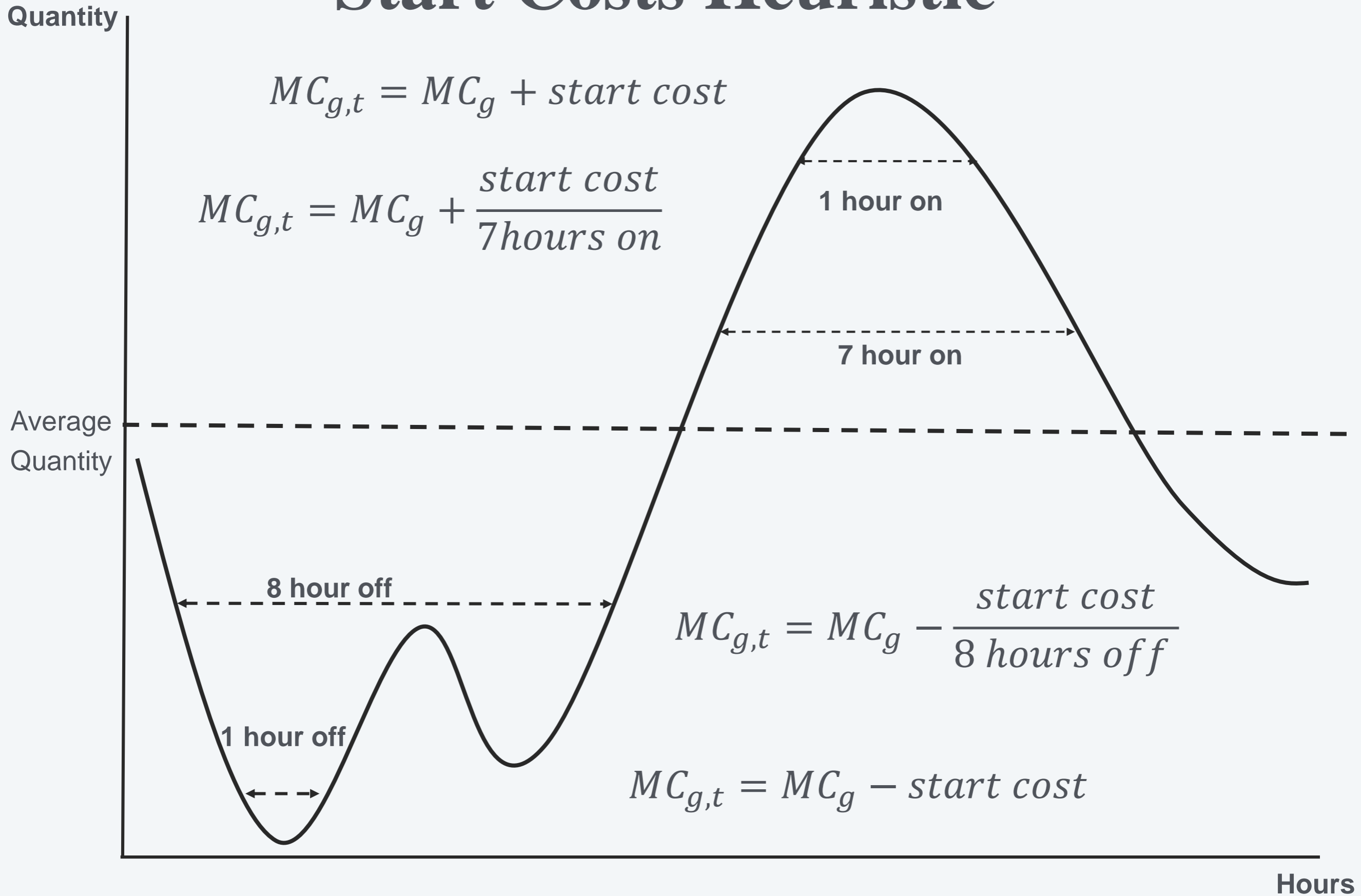
General Approach

- **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)

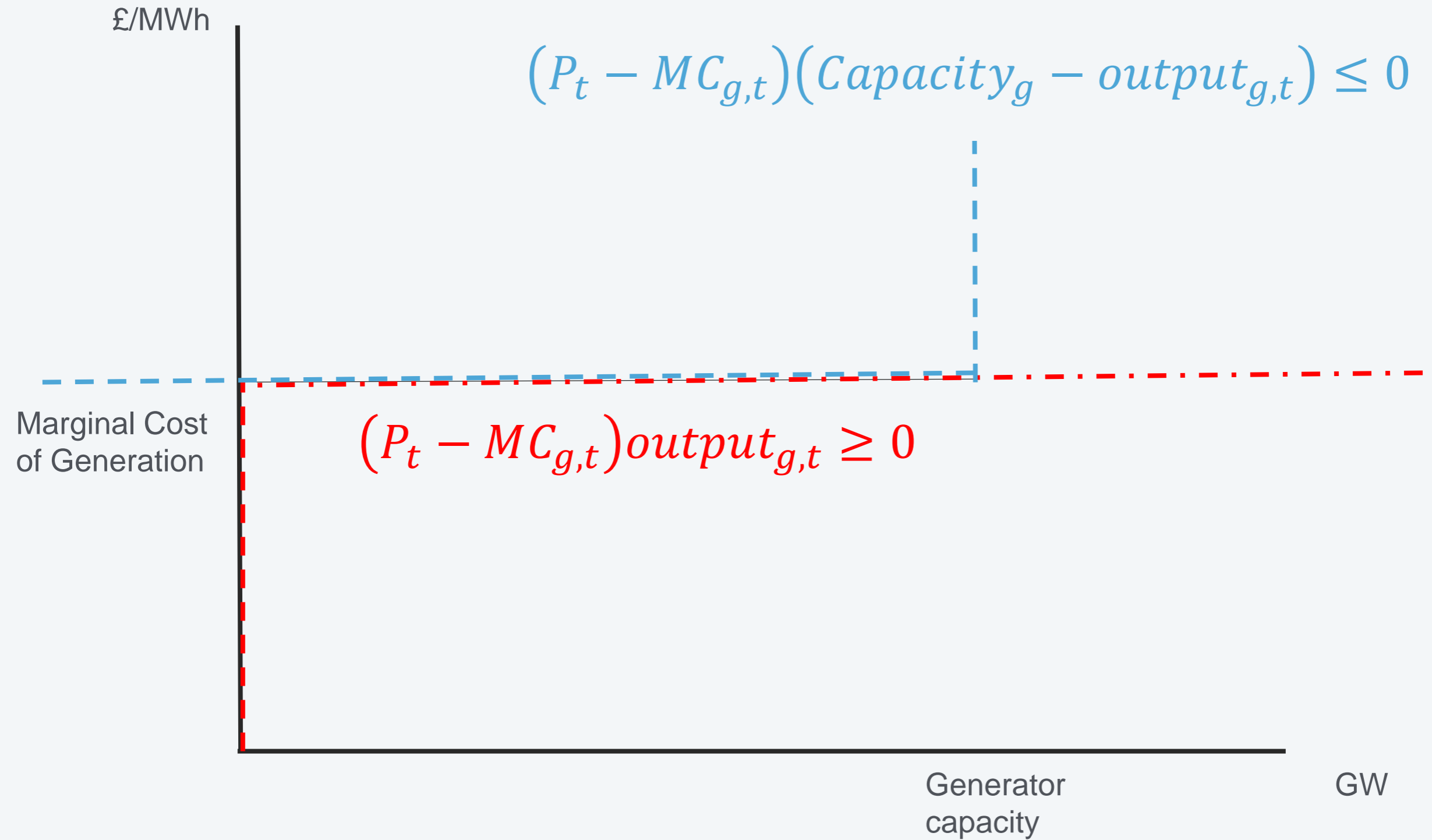
The Merit Order Stack



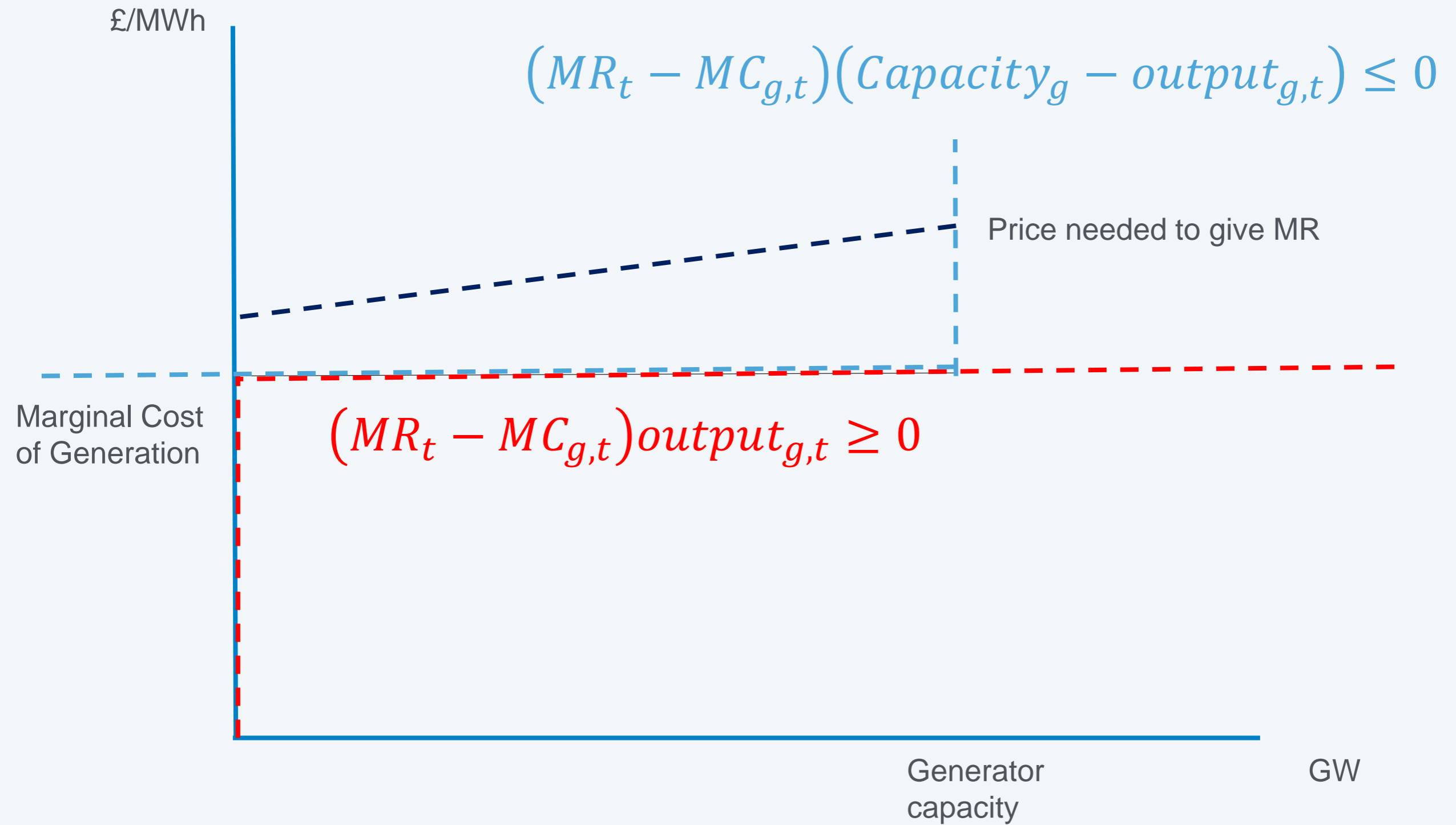
Start Costs Heuristic



A Competitive Generator



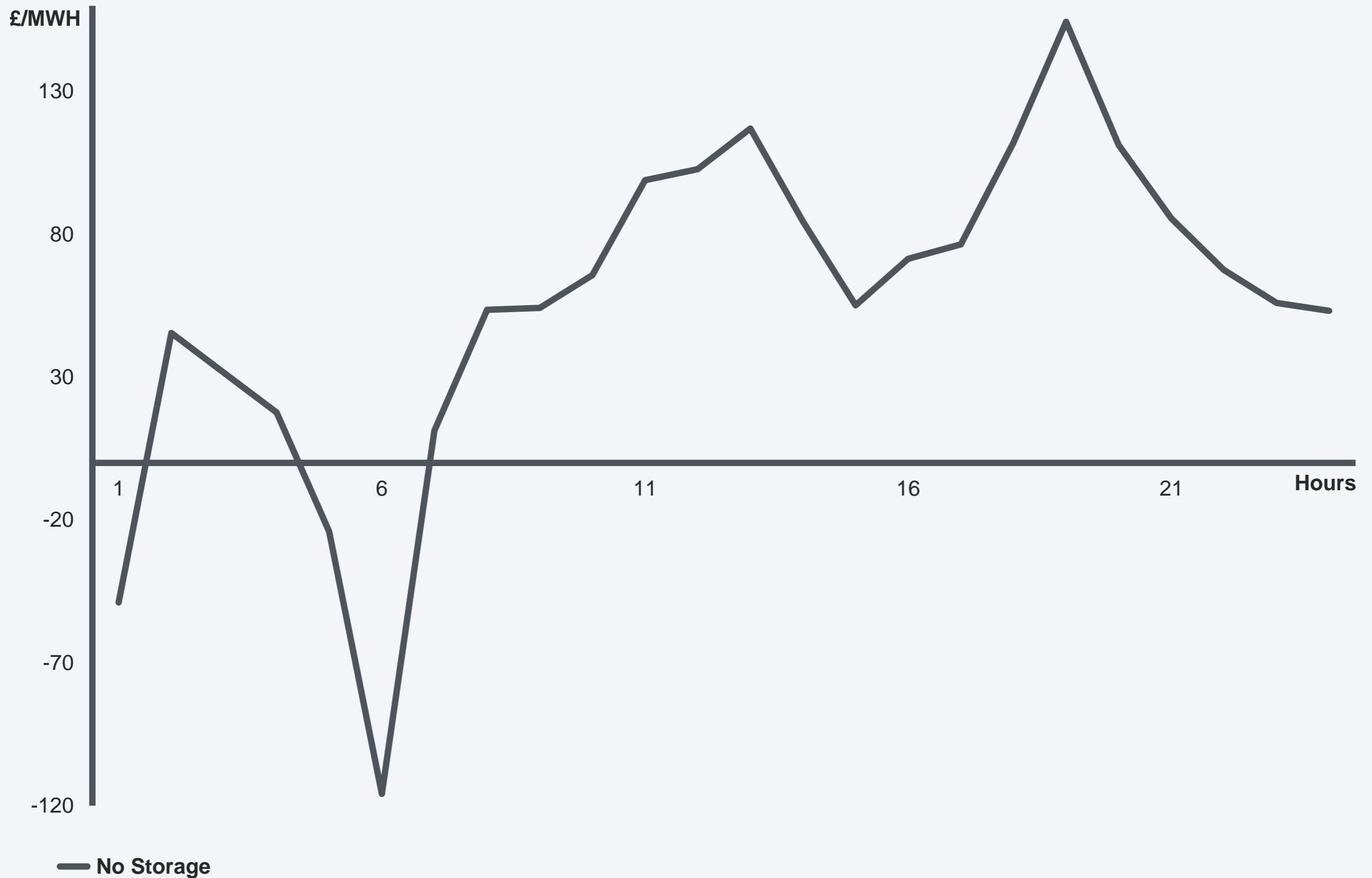
A Strategic Generator



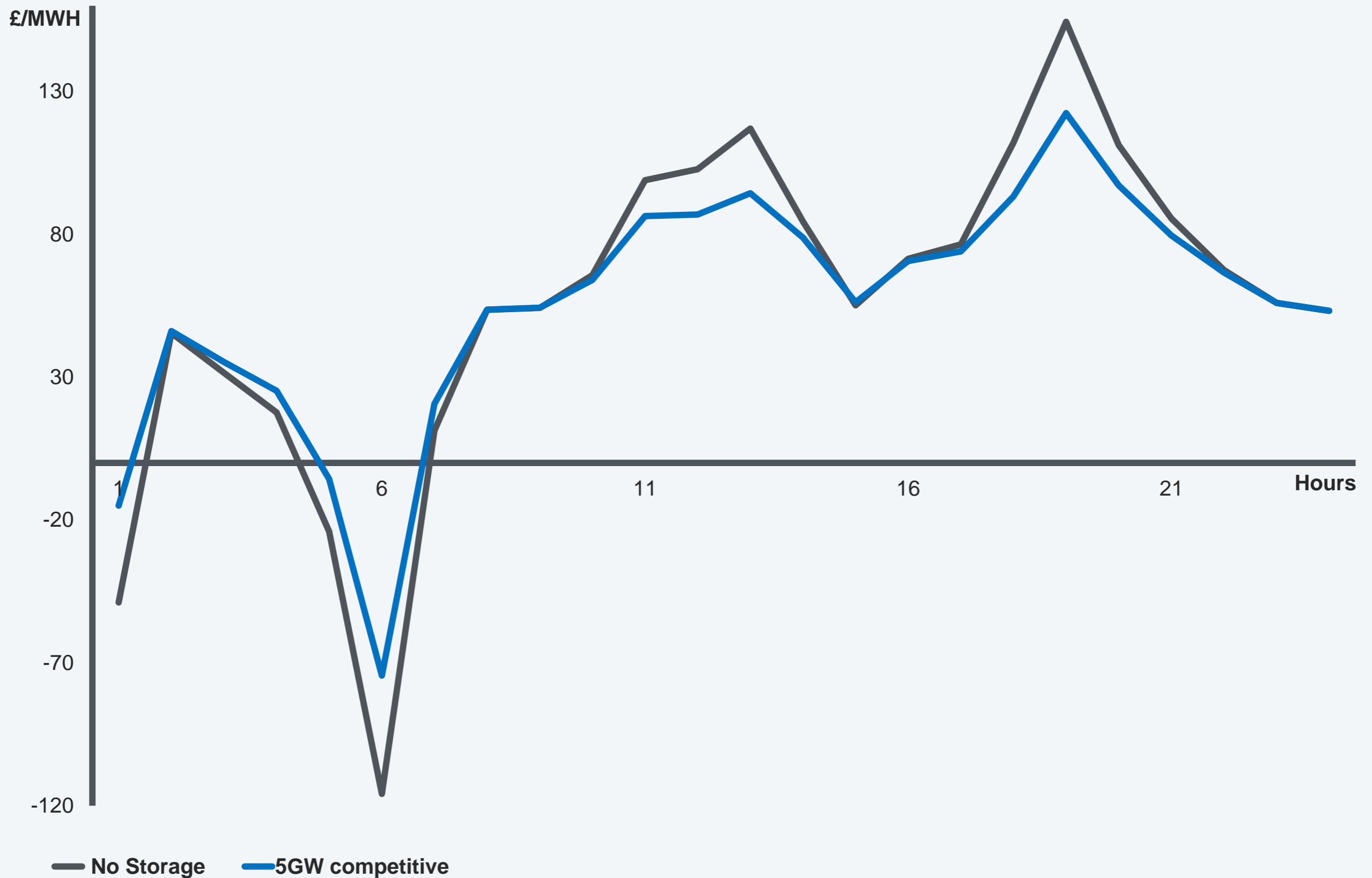
Data

- **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)

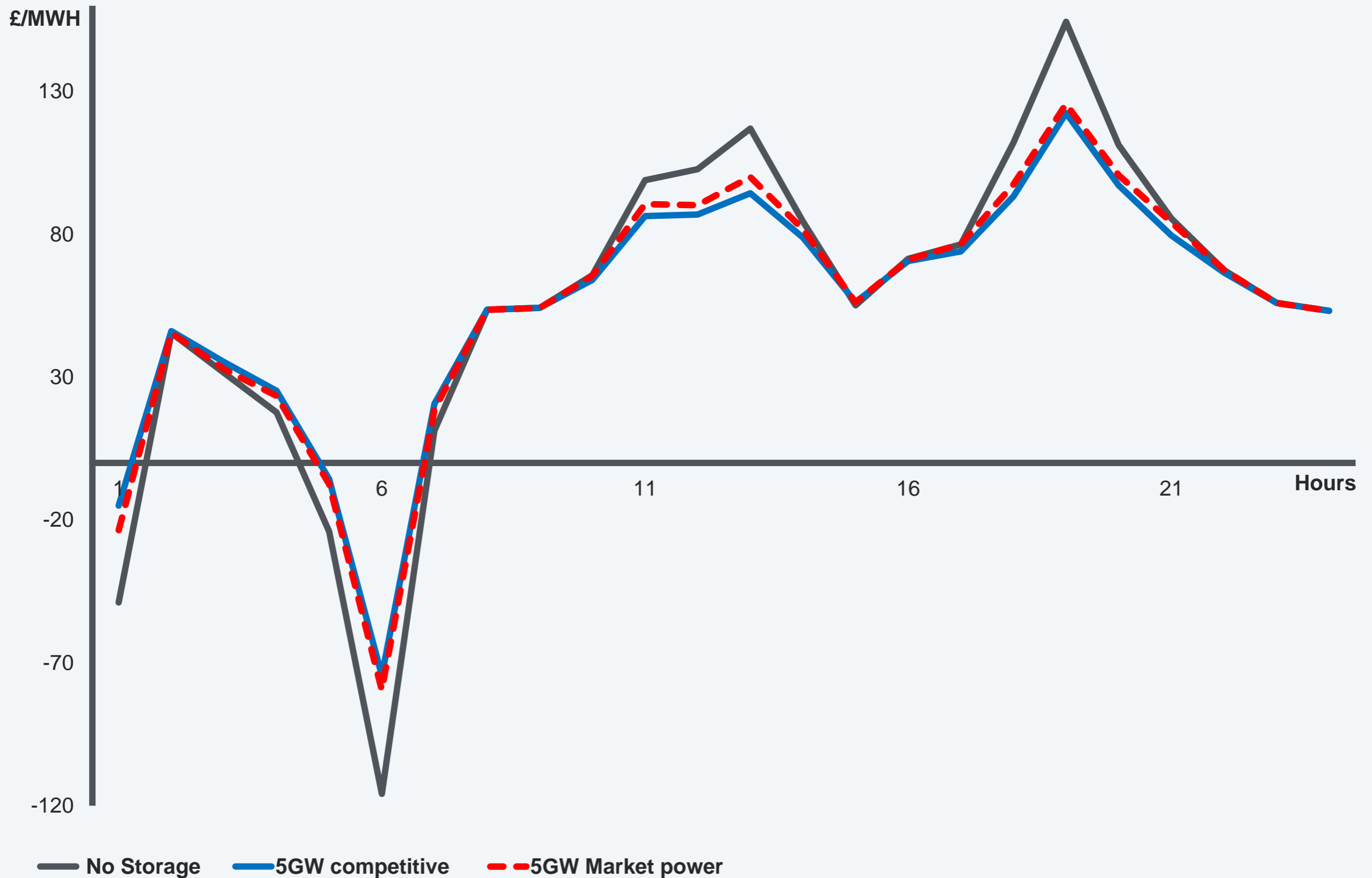
Competitive Generation



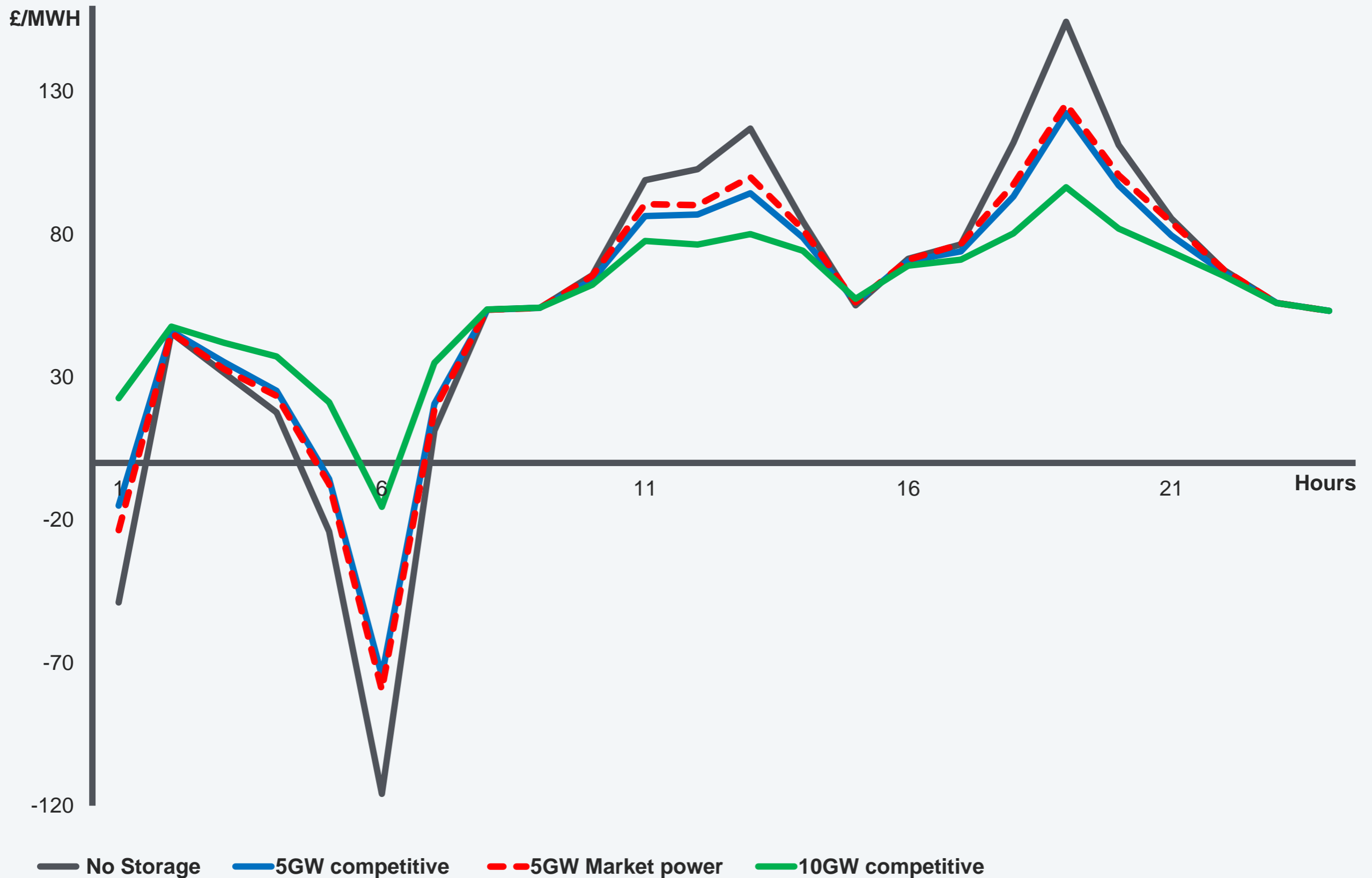
Competitive Generation



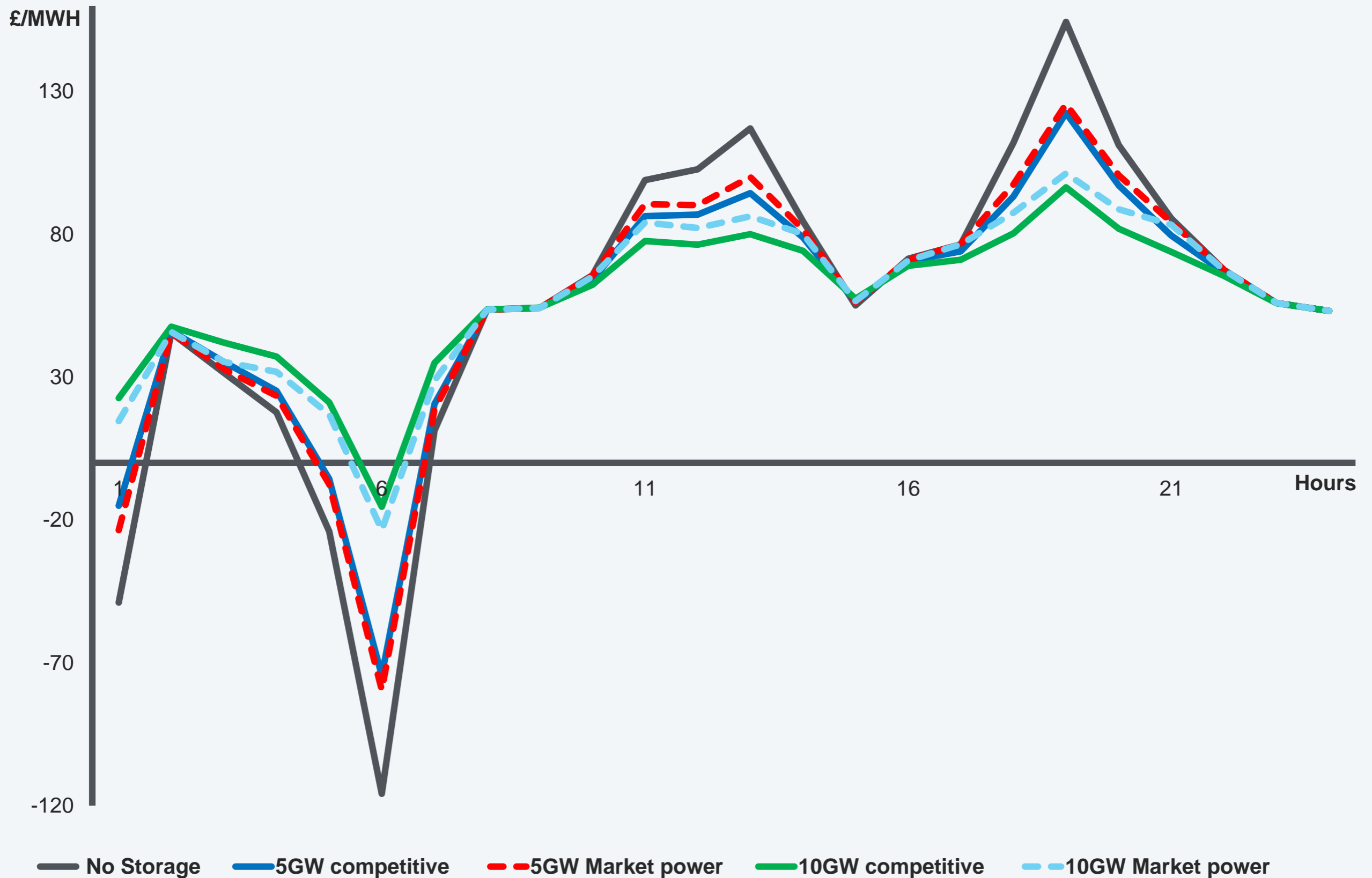
Competitive Generation



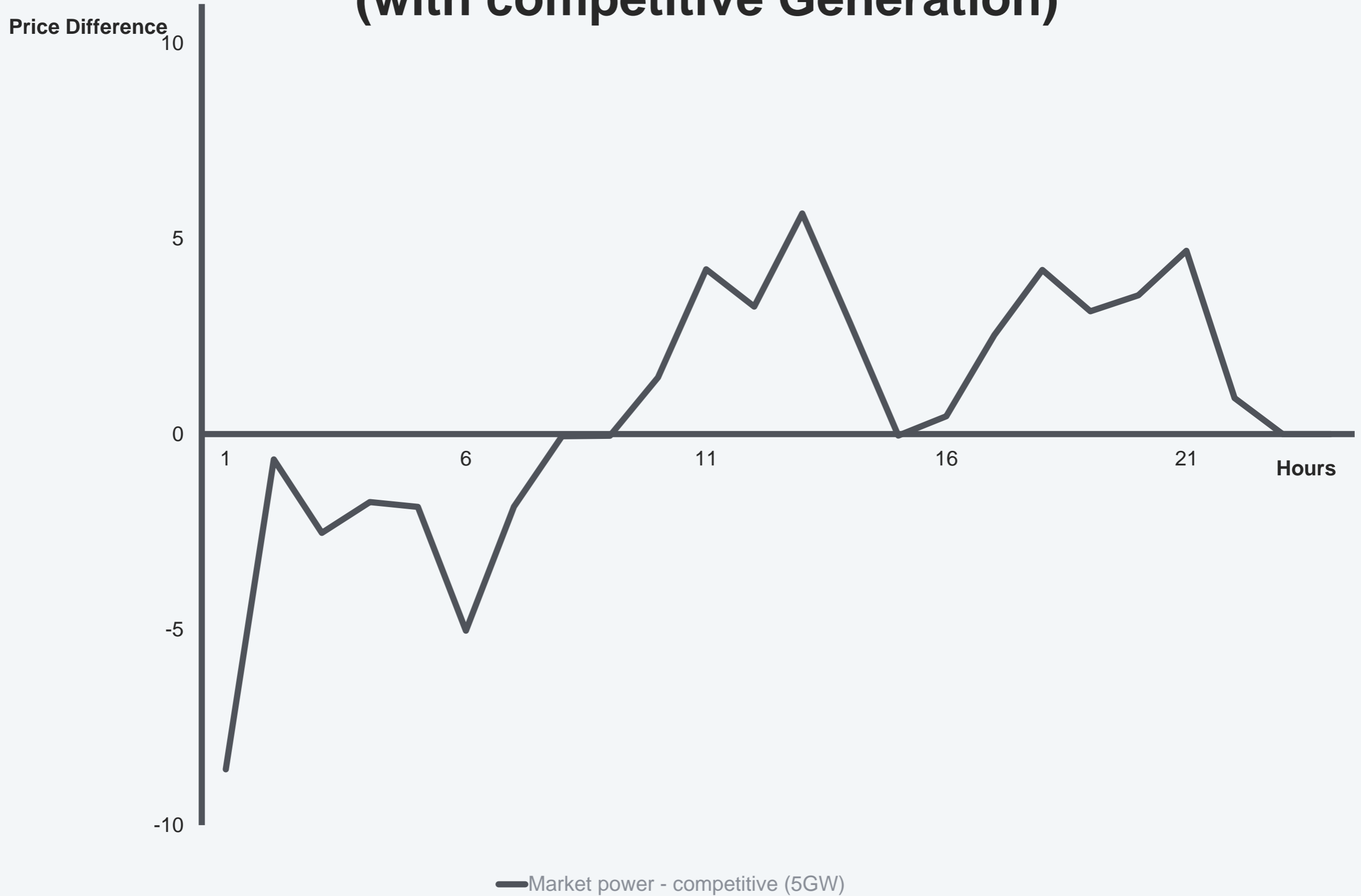
Competitive Generation



Competitive Generation



Impact of market power in storage (with competitive Generation)



Impact of market power in storage (with competitive Generation)

Price Difference

10

5

0

-5

-10

1

6

11

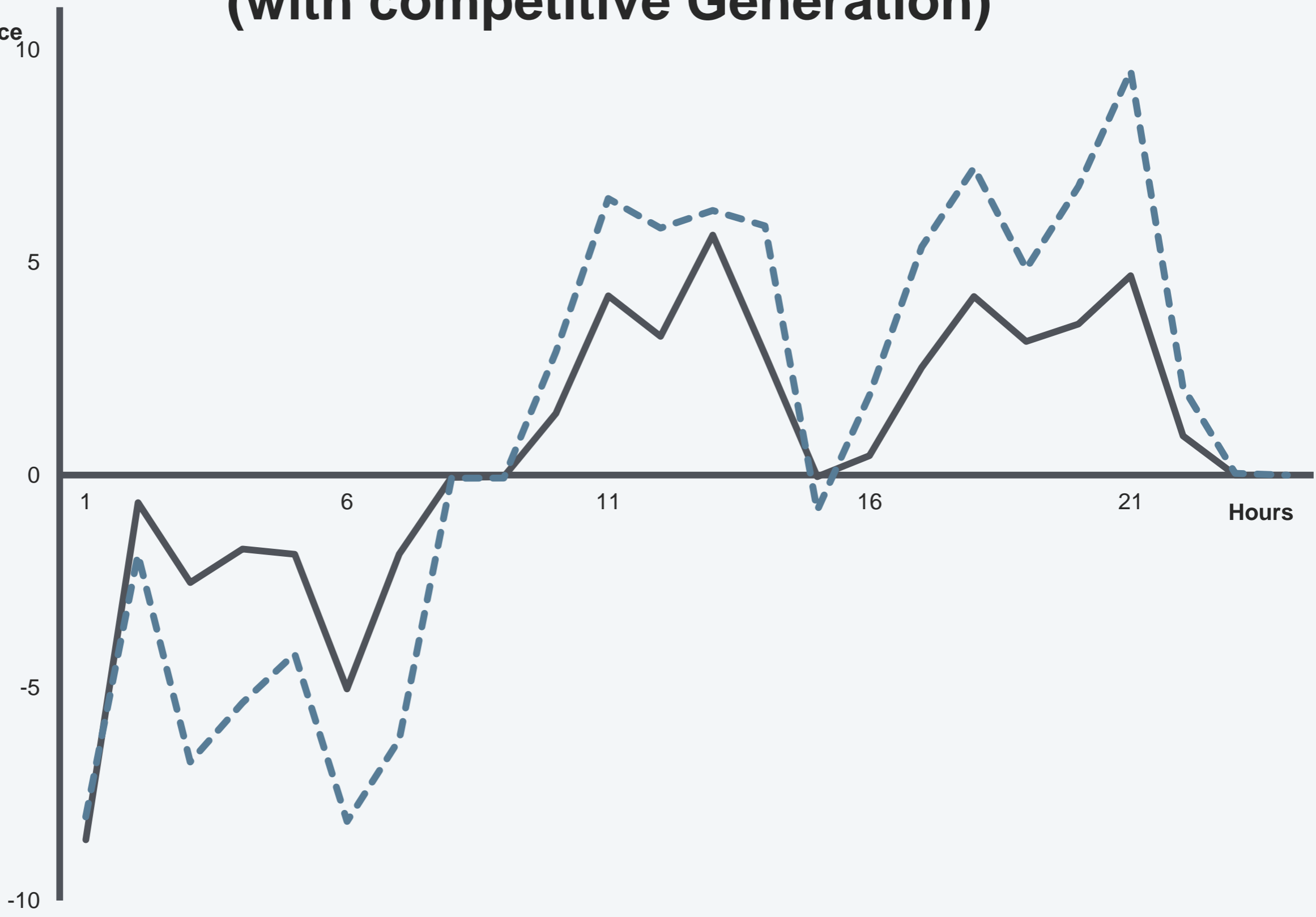
16

21

Hours

— Market power - competitive (5GW)

- - - Market power - competitive (10GW)



Impact of market power in storage (with competitive Generation)

Price Difference

10

5

0

-5

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6

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16

21

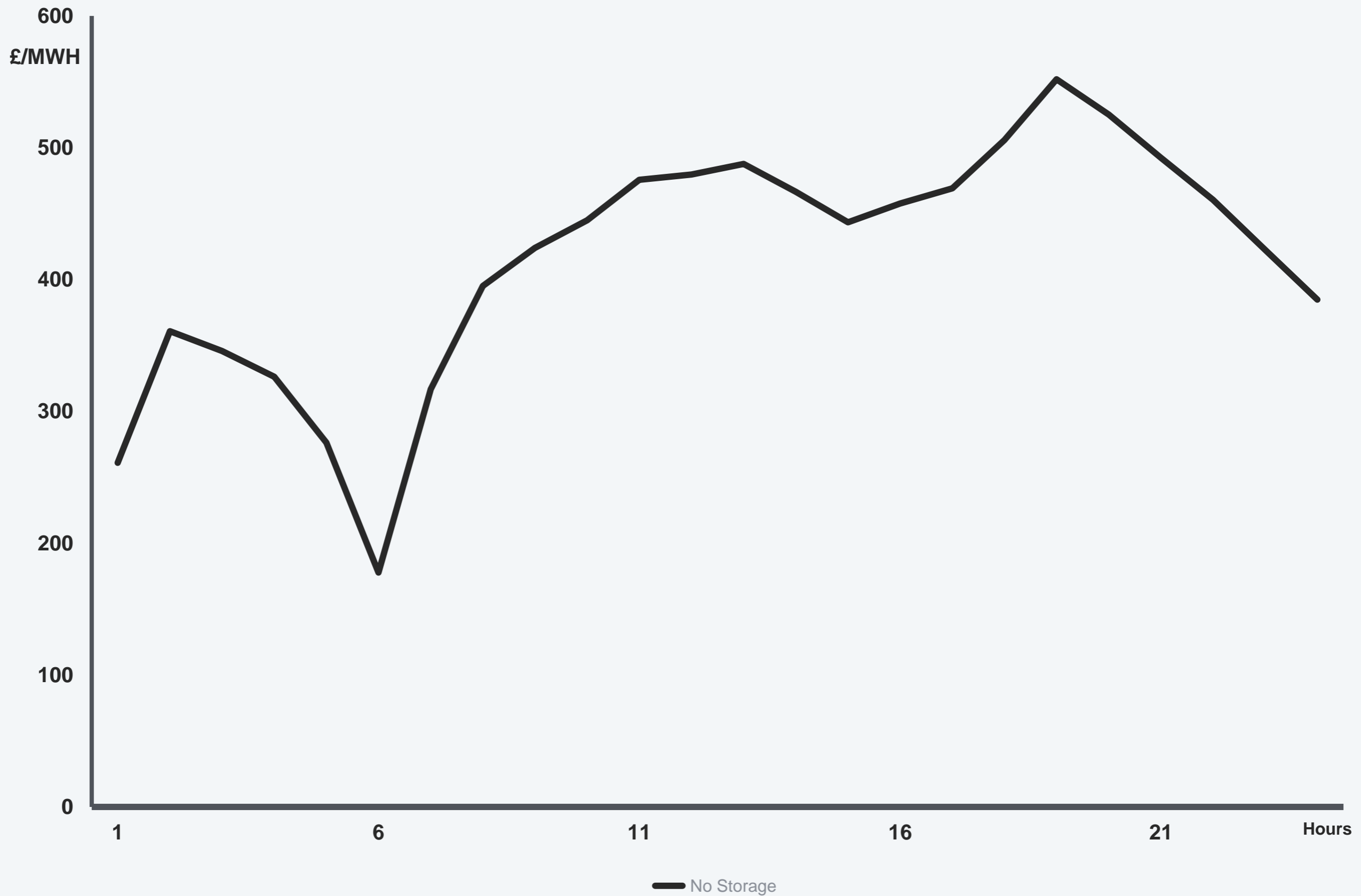
Hours

— Market power - competitive (5GW)

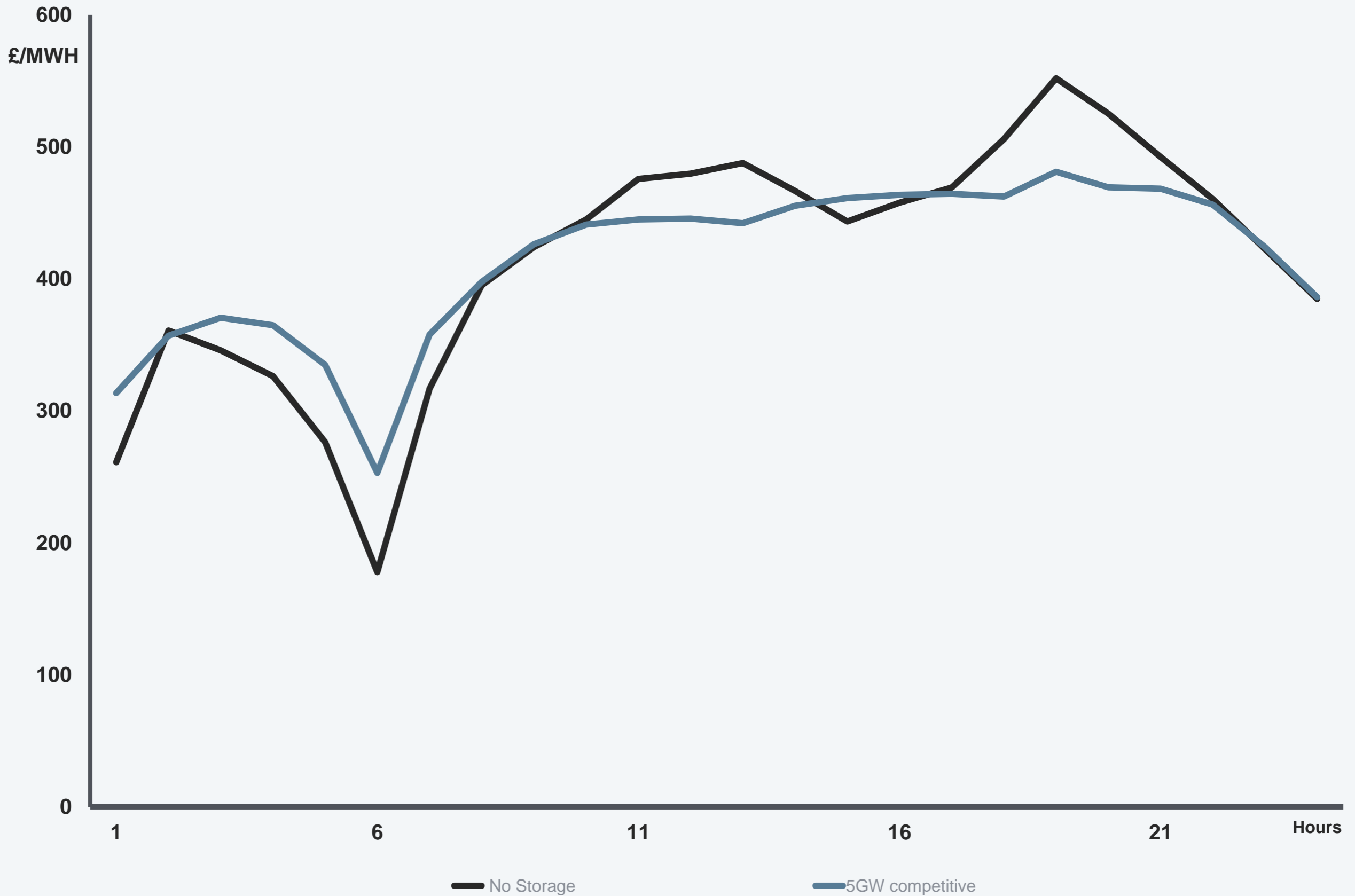
- - - Market power - competitive (10GW)

••• Market power - competitive (40GWH)

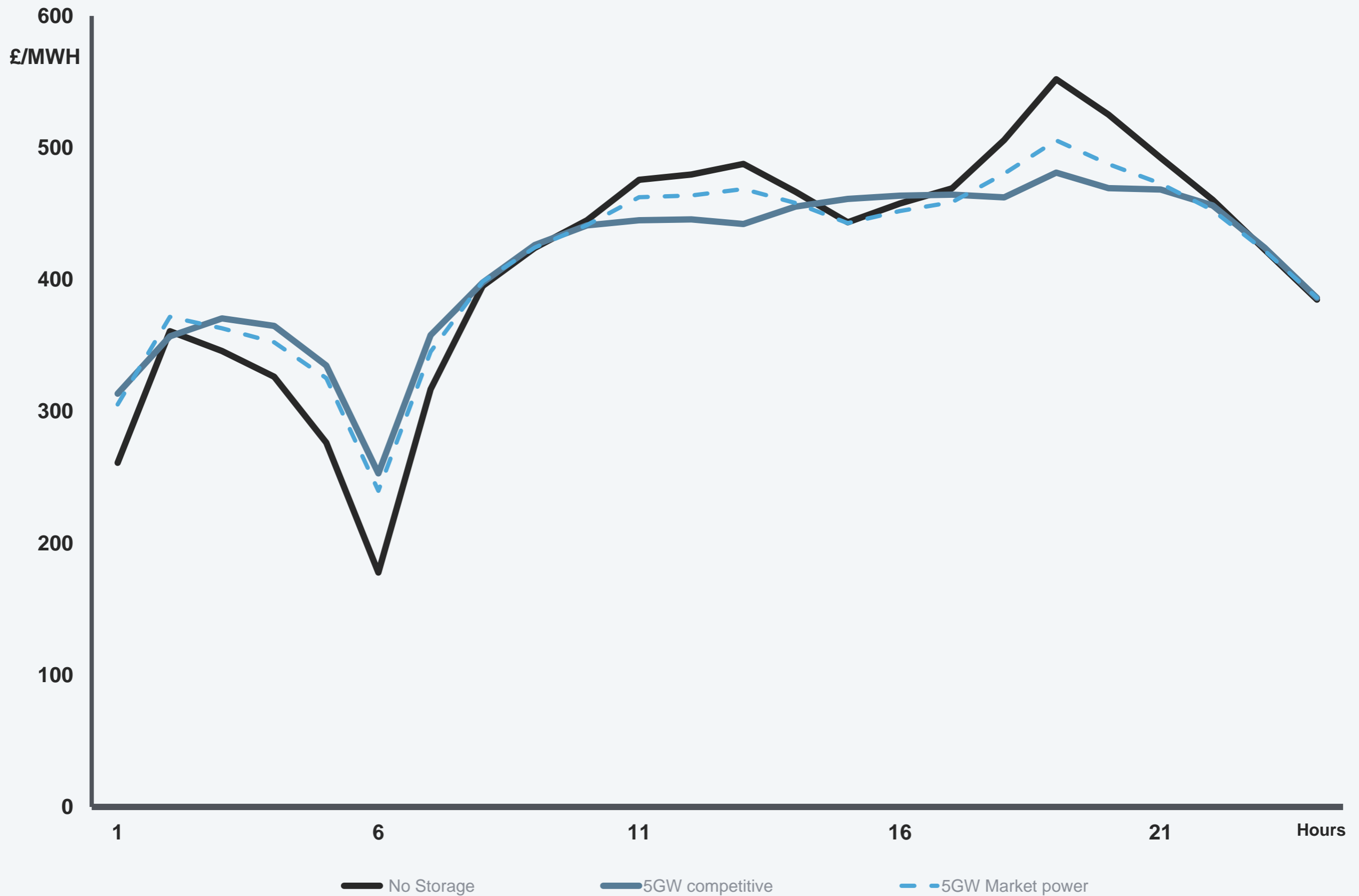
Strategic Generation



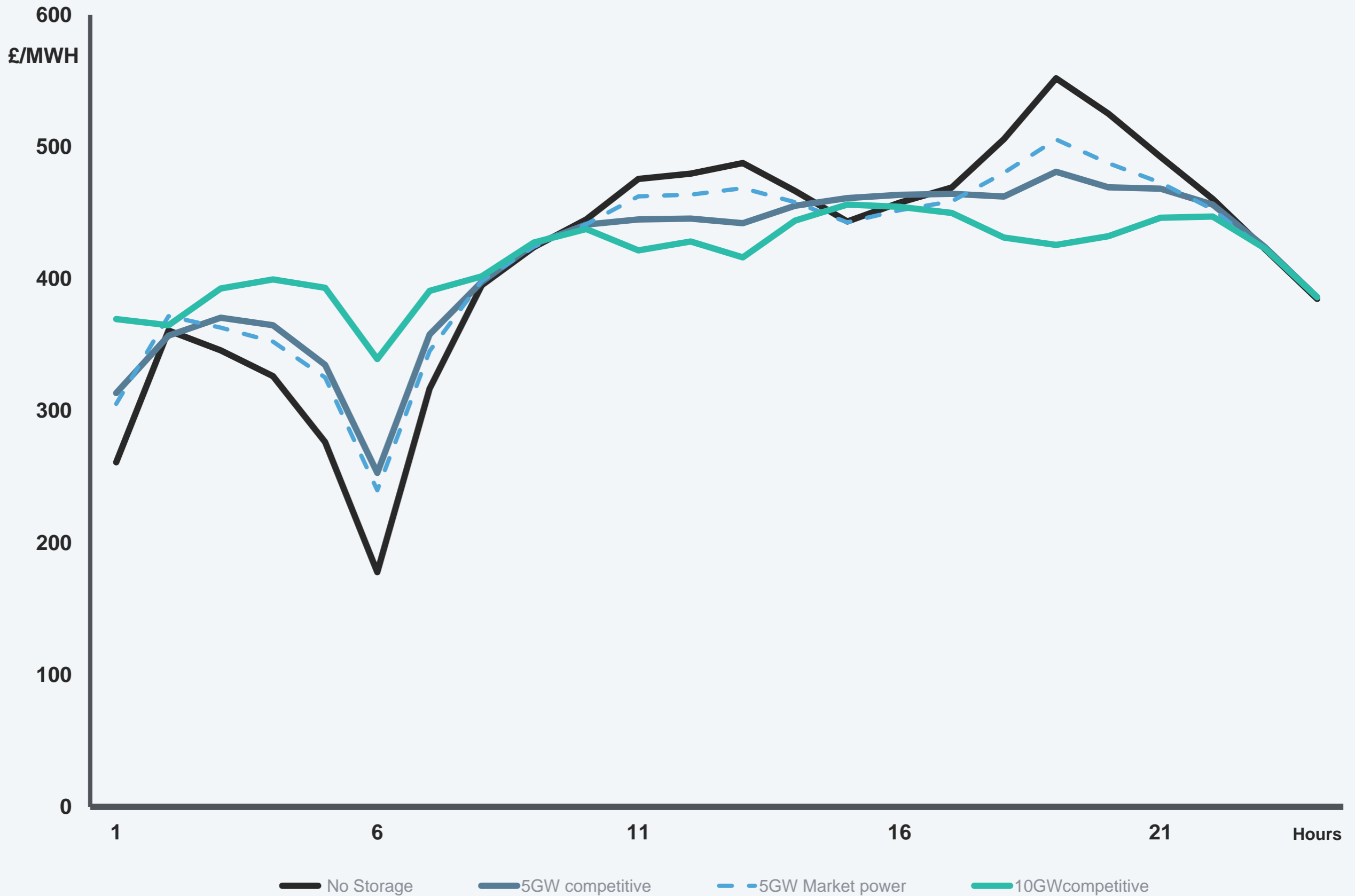
Strategic Generation



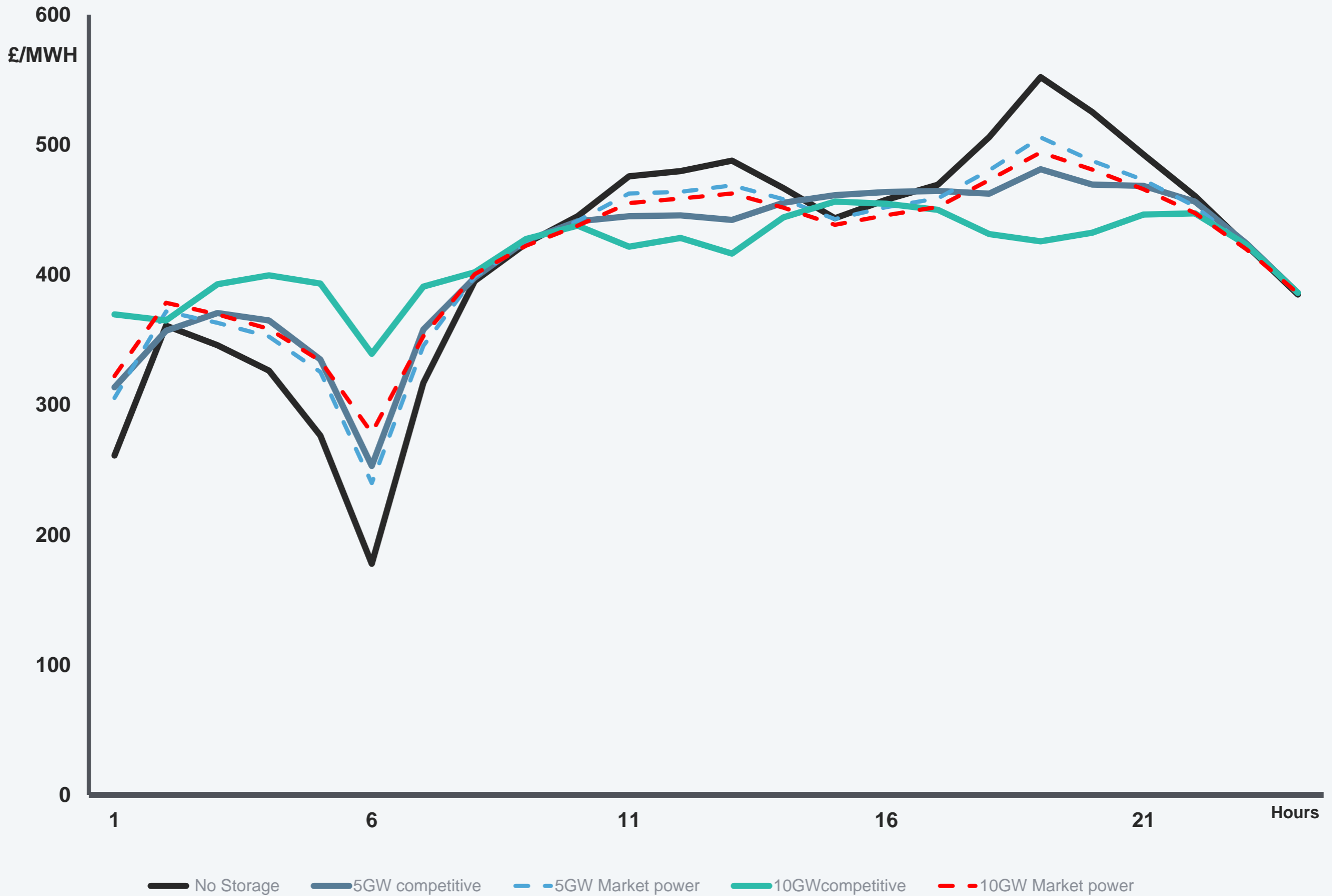
Strategic Generation



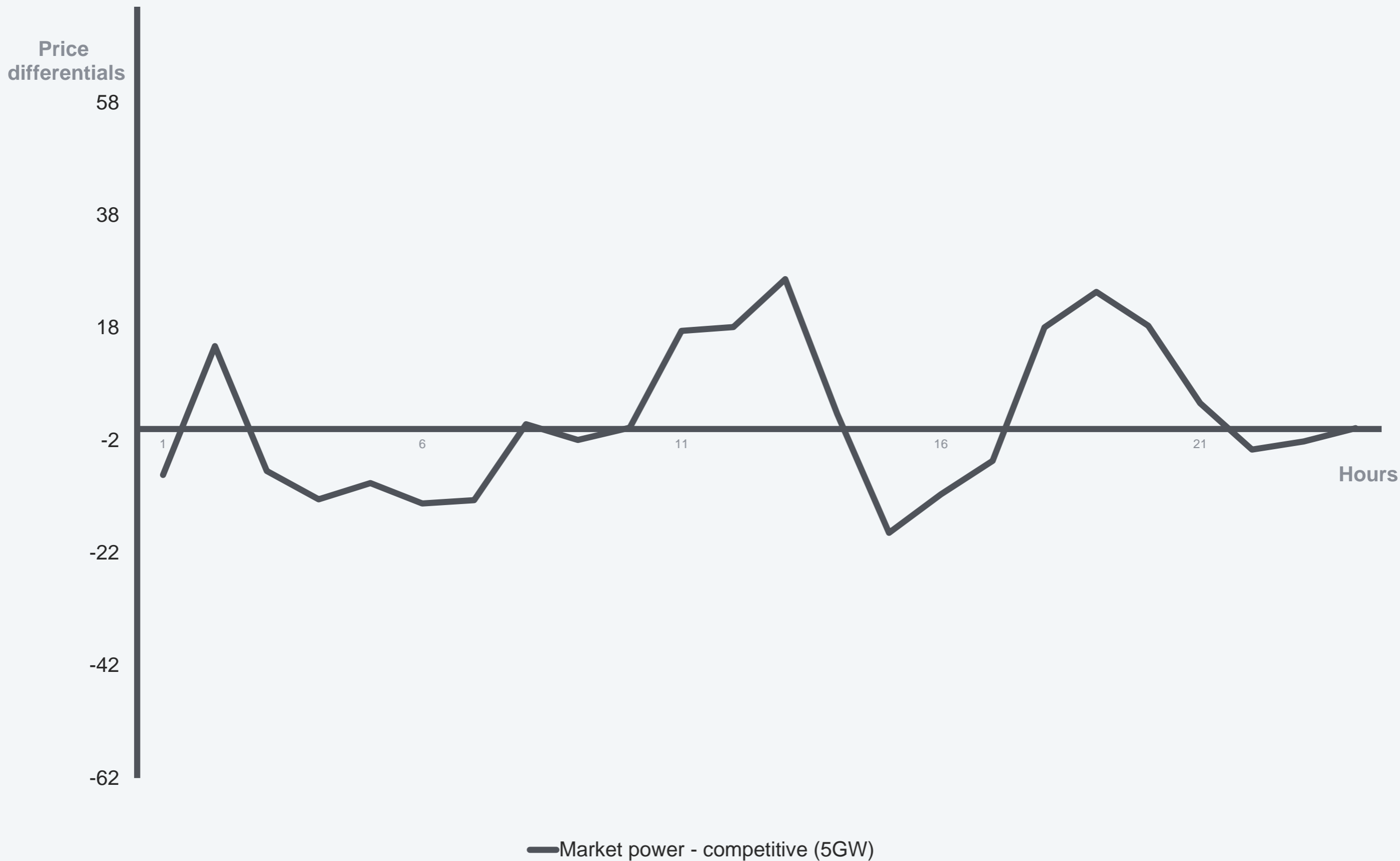
Strategic Generation



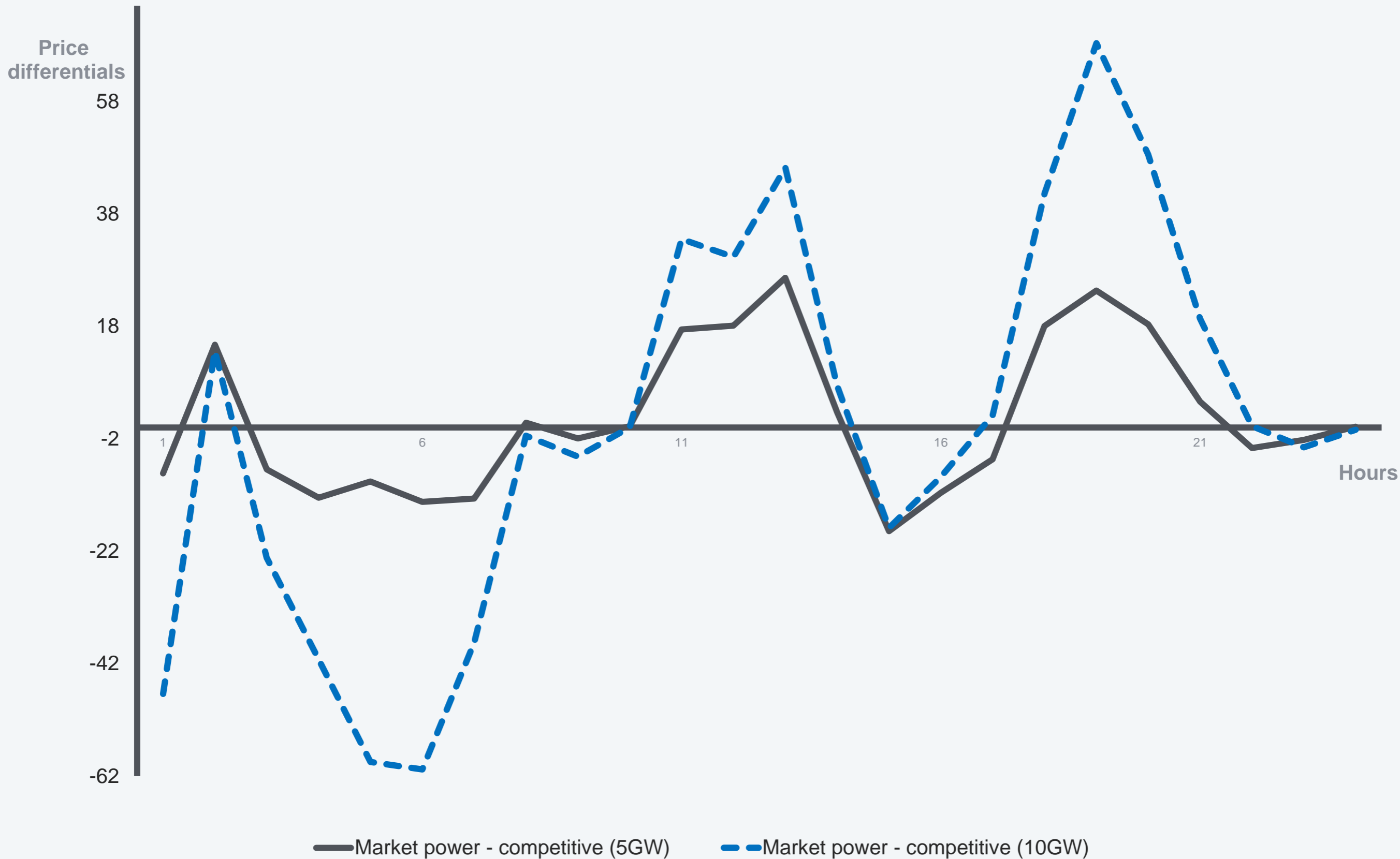
Strategic Generation



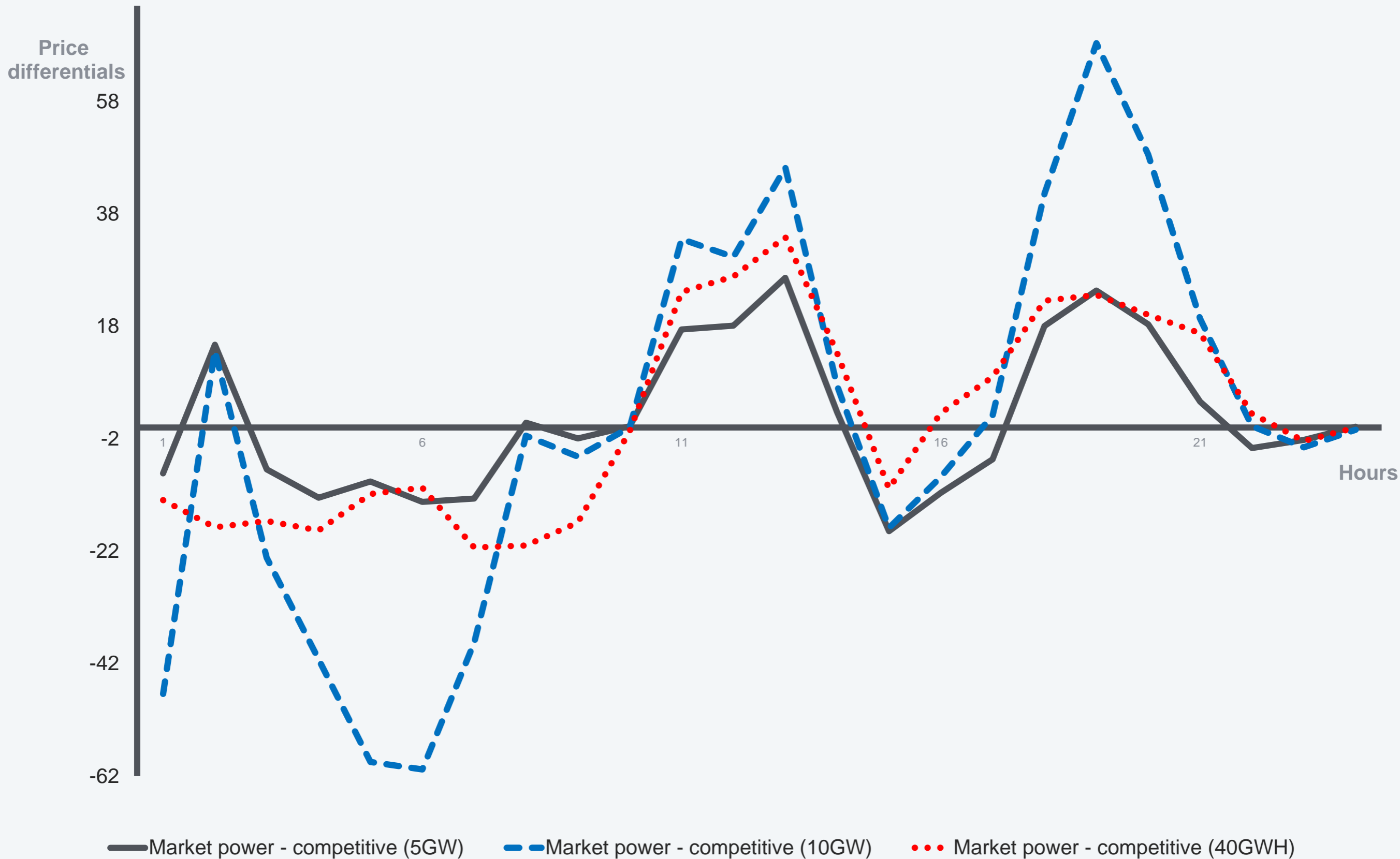
Price differential with Strategic Generation



Price differential with Strategic Generation



Price differential with Strategic Generation



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 losses 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



References

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