



The Economics of Flexibility

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 Speech bubbles contain comments that can be read by moving the mouse over them

13 December 2019

What is flexibility?

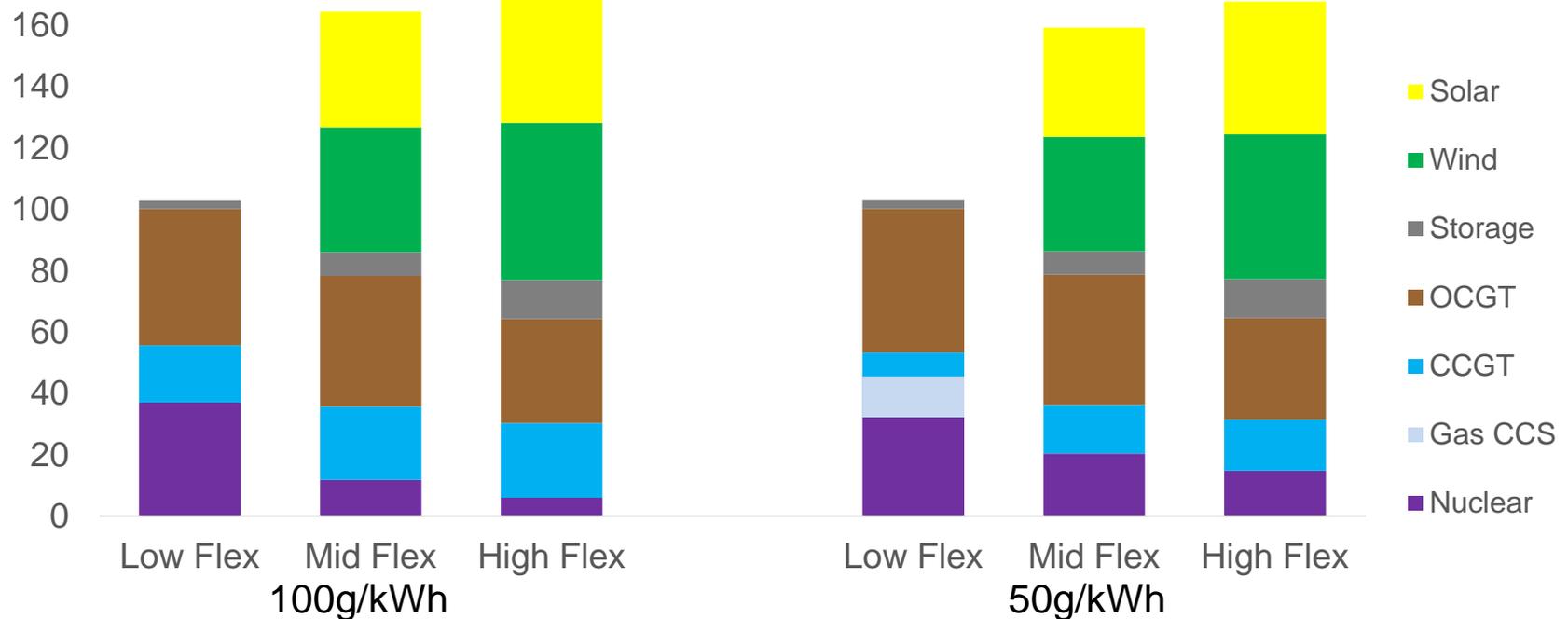
- Flexibility is the ability to respond to the changing needs of the power system
 - Generators
 - Demand response
 - Storage
 - Transmission



Does it matter?

- £6bn per year cost saving for a 50g/kWh power system
- £4.5bn per year for a 100g/kWh system

GW of capacity



Will we deliver it?

- Flexibility involves a range of services from a range of providers, some currently unpriced
- How do we coordinate everything?
- What are the right incentives?
- How large are the transactions costs?



Why is flexibility needed?

Constrained Optimisation

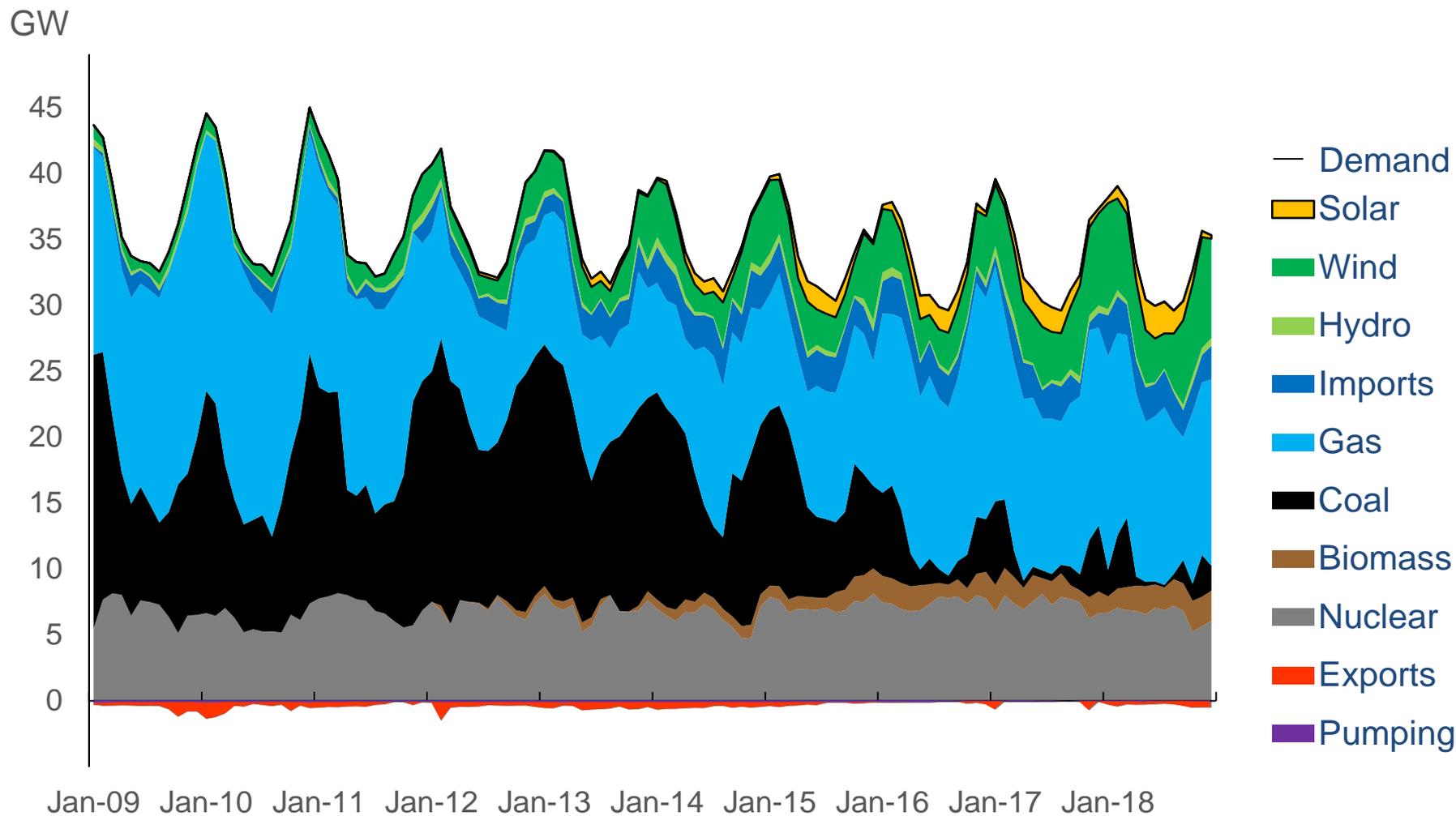
(making the power system work)

- Generation = Demand + Losses
+ net Storage + net Exports
- Line Flows \leq Limits
- Voltages within acceptable ranges (reactive power)
- Generators meeting their own constraints
 - Minimum on/off times
 - Maximum ramp rates
 - Minimum stable generation
- Reserves sufficient, given risks and response times



Generation in Great Britain

Monthly averages





Renewable Generators...

(wind and solar)

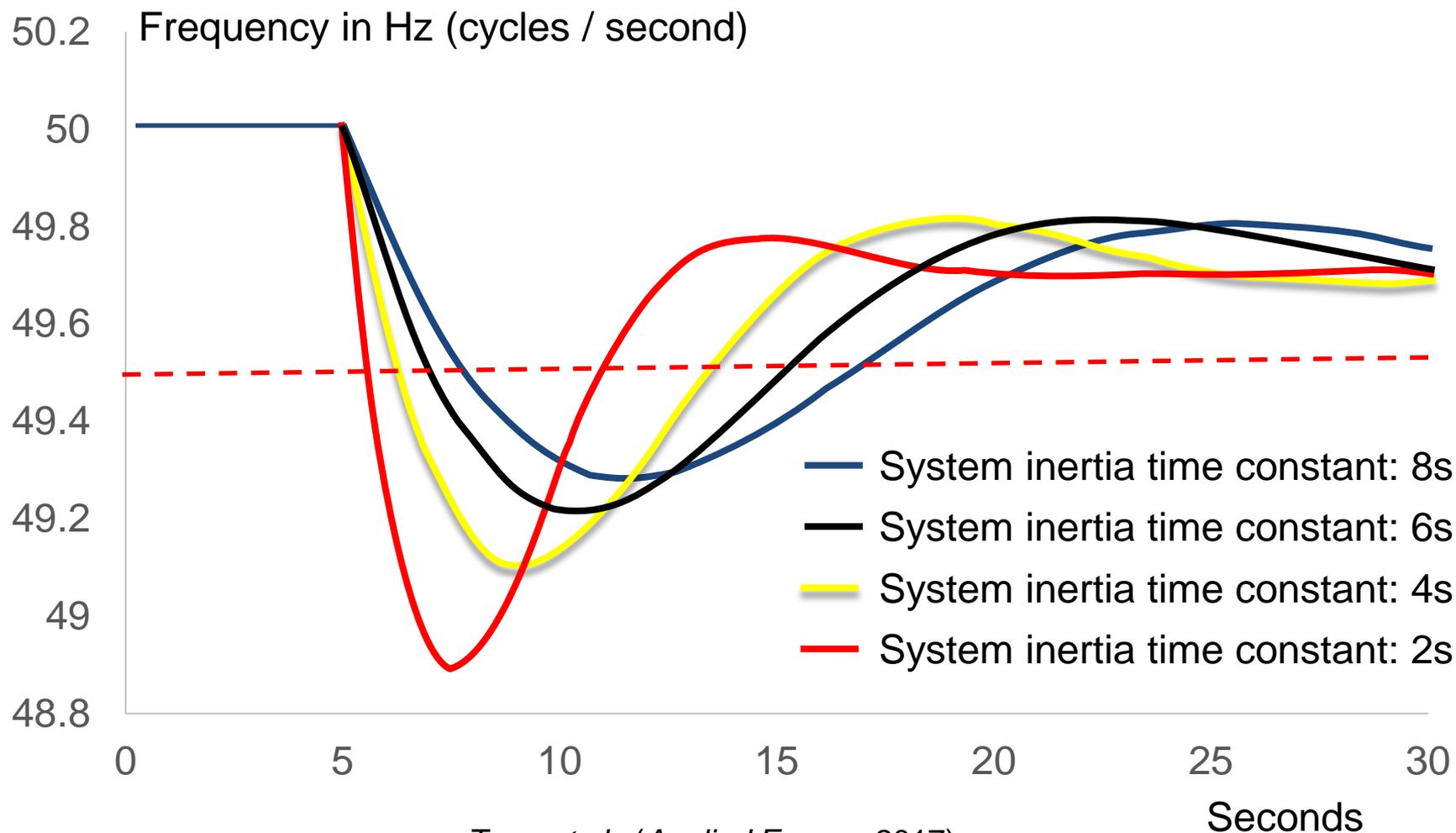
- may be more likely to...
 - be in the wrong place relative to load
 - be at the wrong time relative to load
 - have too little inertia





The importance of inertia

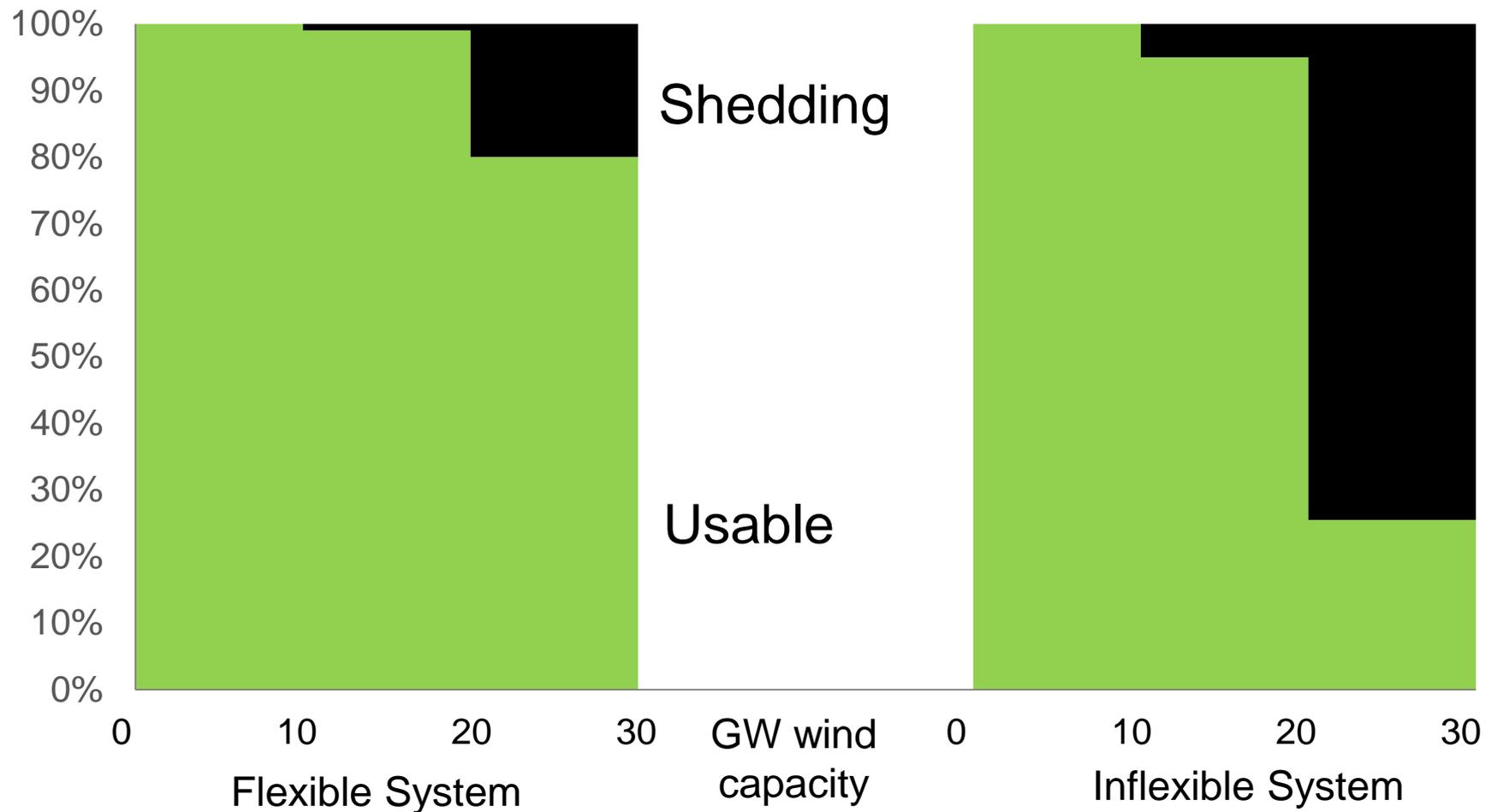
Post-fault system frequency





Acceptable wind output

System may not be able to absorb it



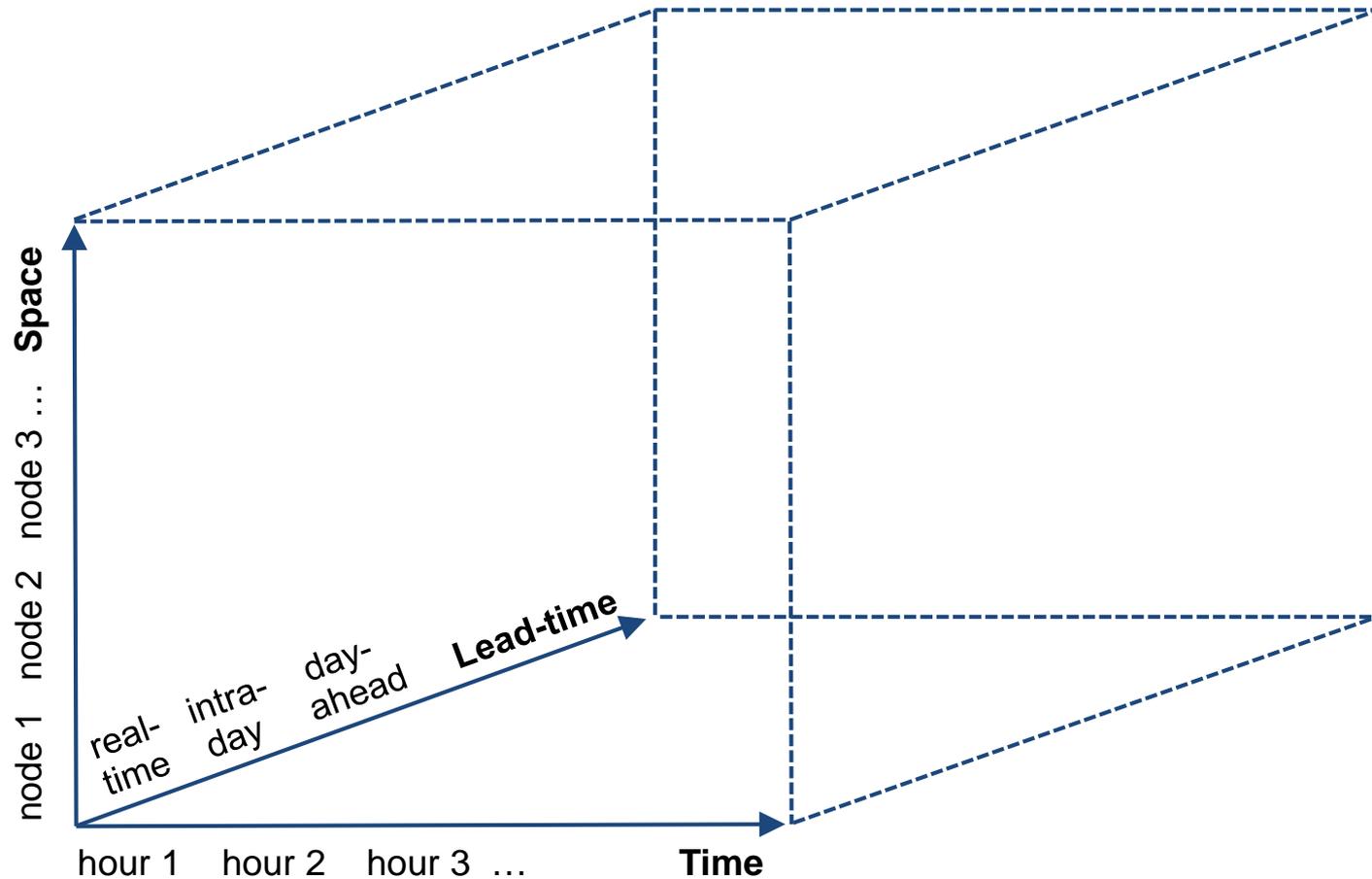


Three-dimensional electricity



Lion Hirth's framework

Renewable Energy, 2015



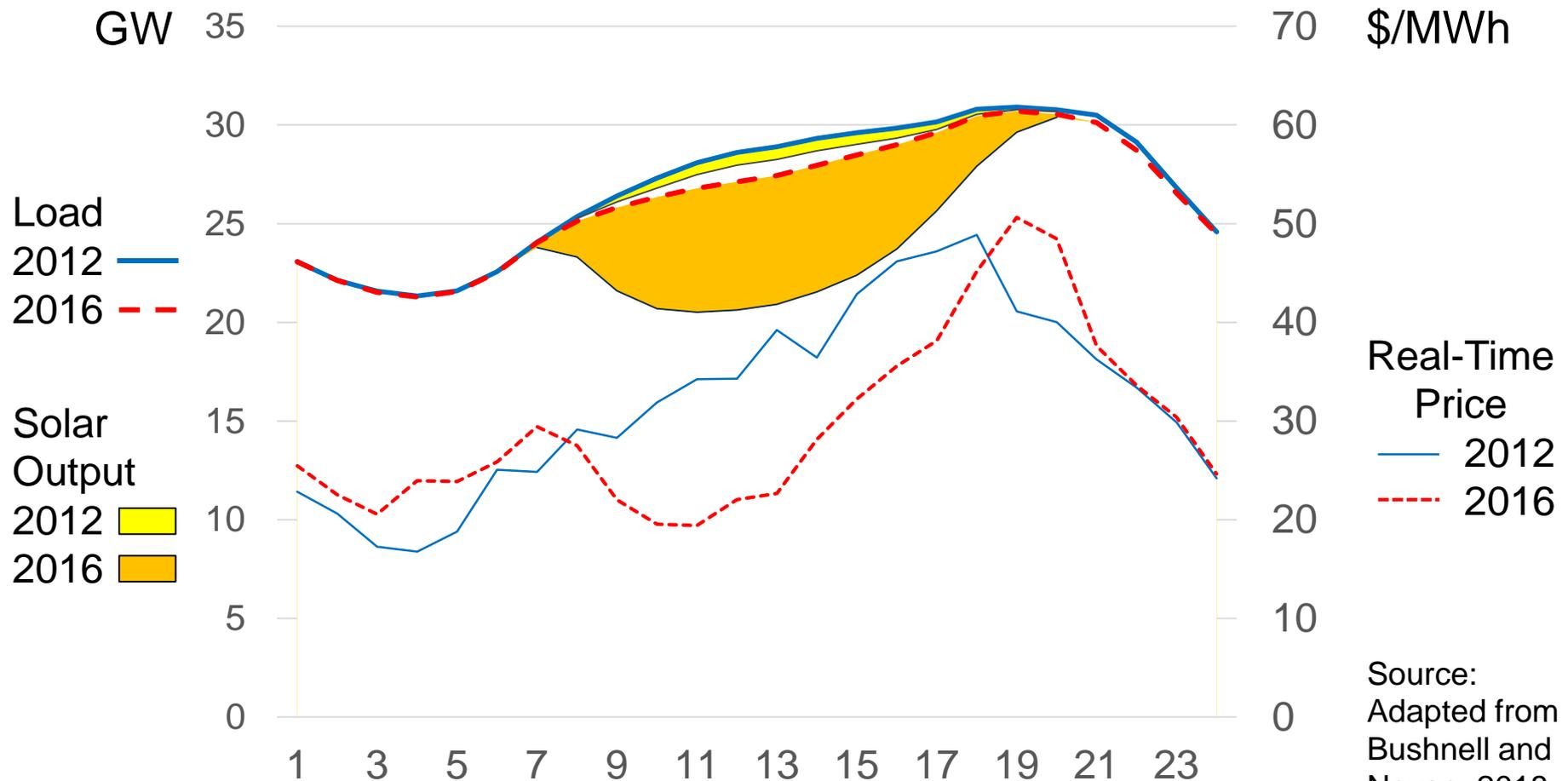


When does “free” electricity mean higher prices?

Price variation over time

Load, PV Output and Prices

California, 2012 and 2016



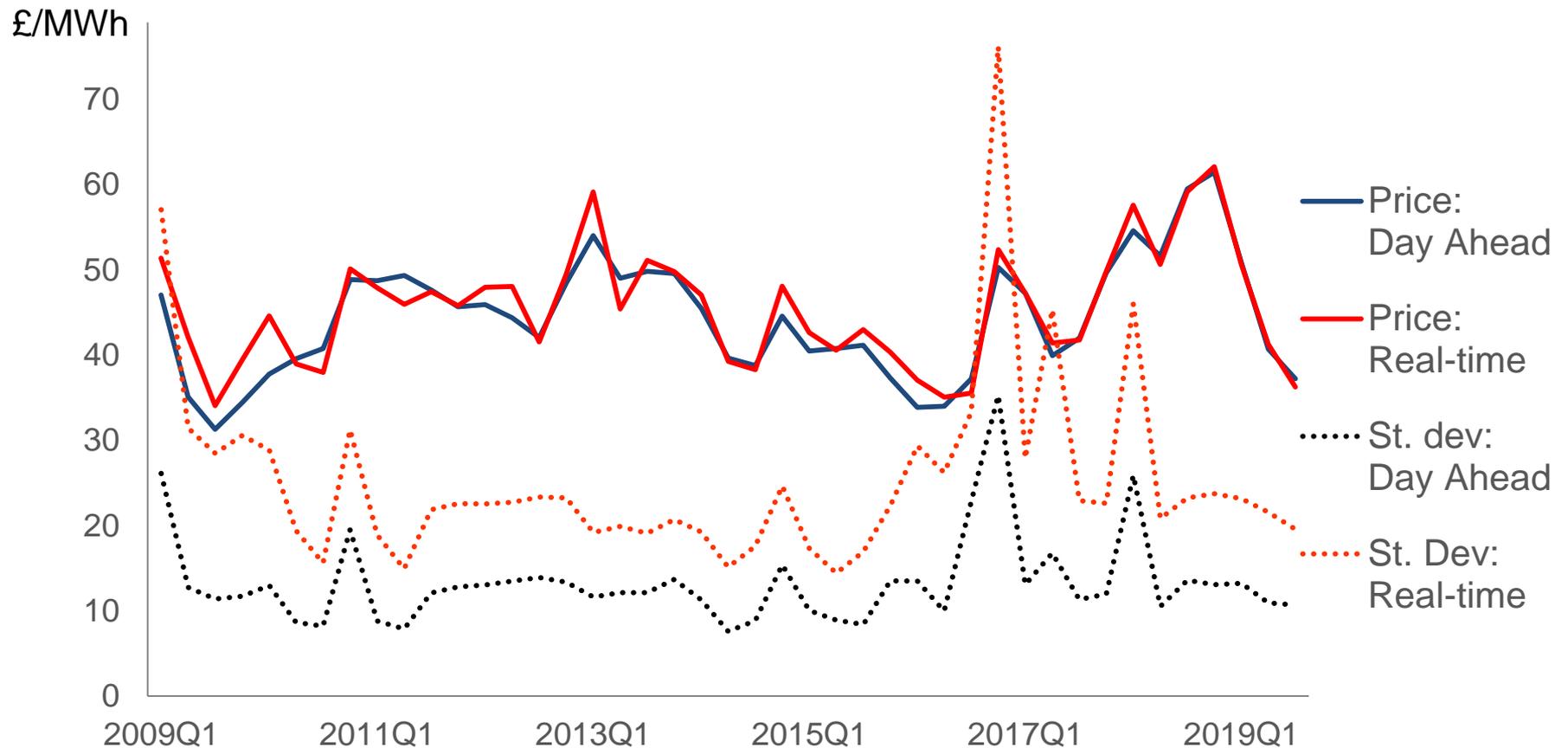
Source:
Adapted from
Bushnell and
Novan, 2018



Risk in real-time trading



Day-ahead and Real-time Prices



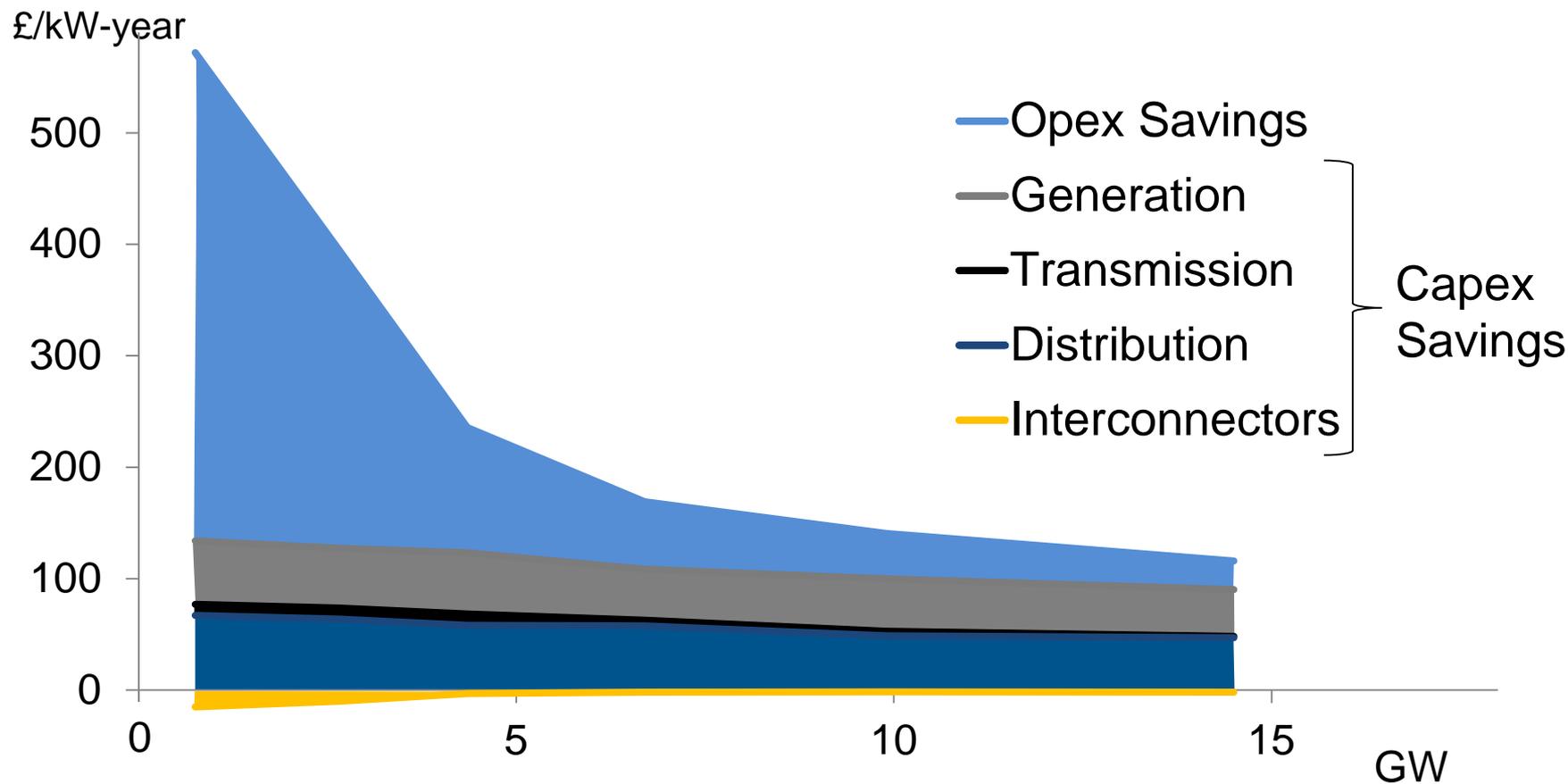


**The value of flexibility will
rise over time**



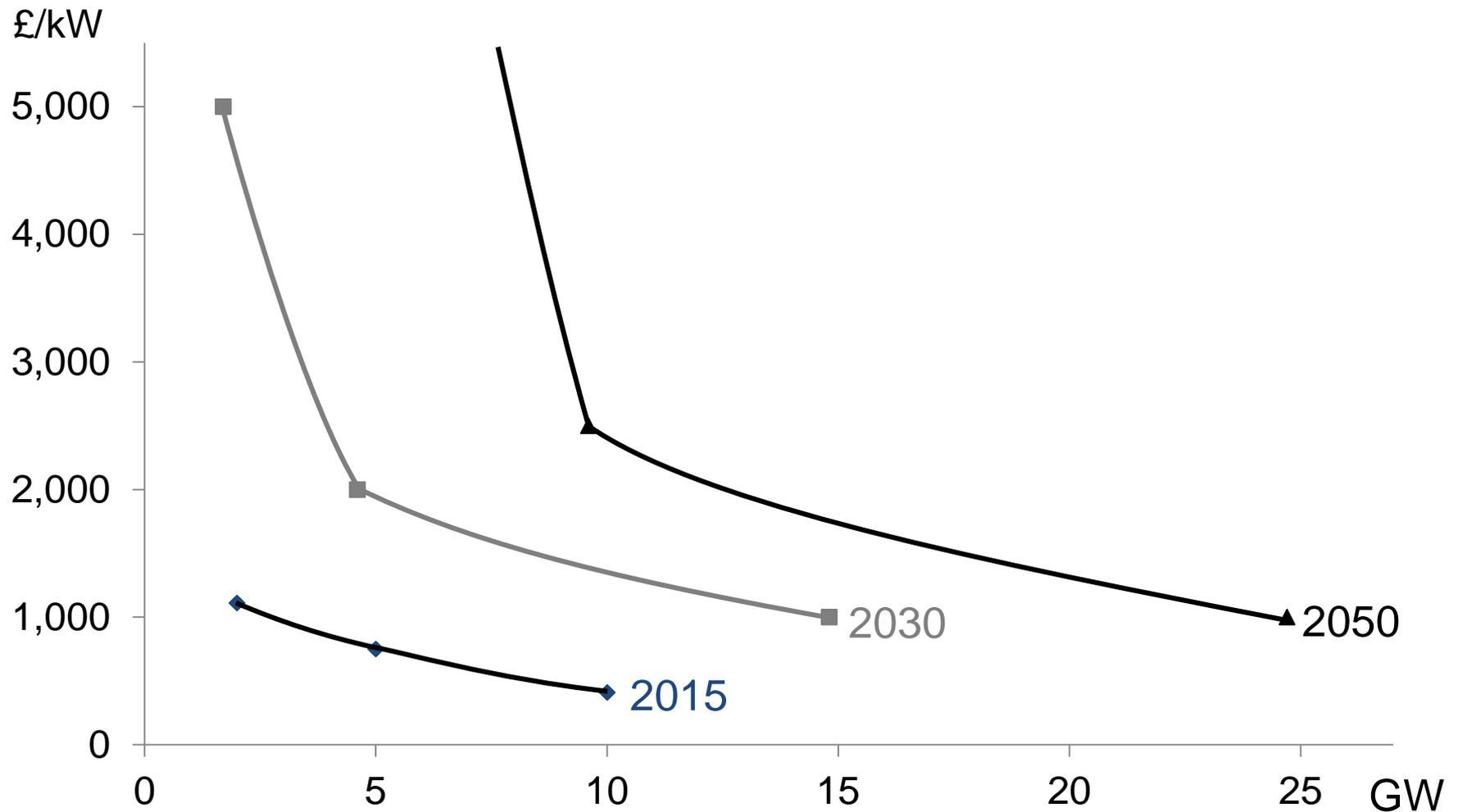
Marginal Value of Storage

(Strbac *et al.*, 2012)





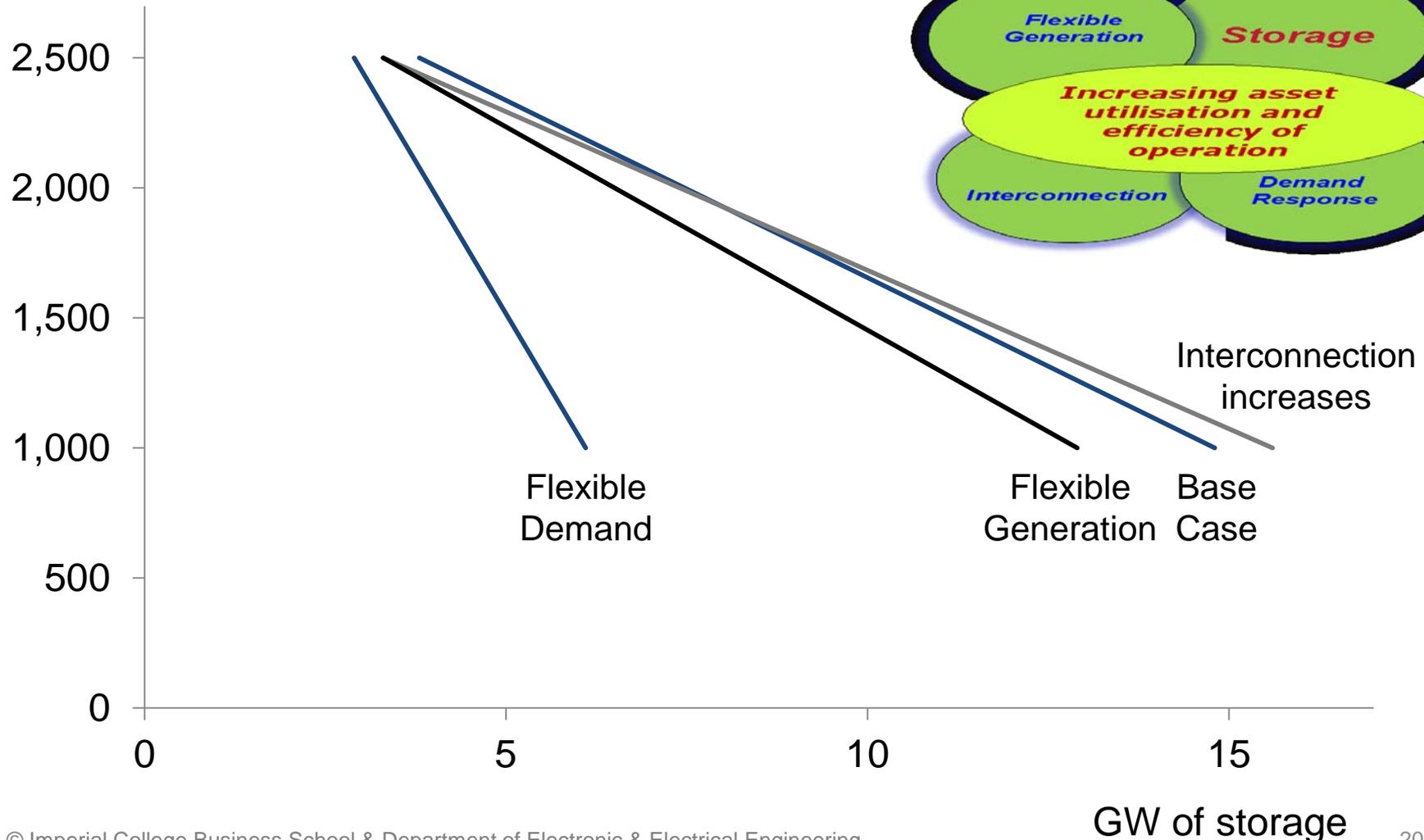
The value of storage over time





What about the competitors?

NPV of storage, £/kW



Interconnection increases

Flexible Demand

Flexible Generation

Base Case

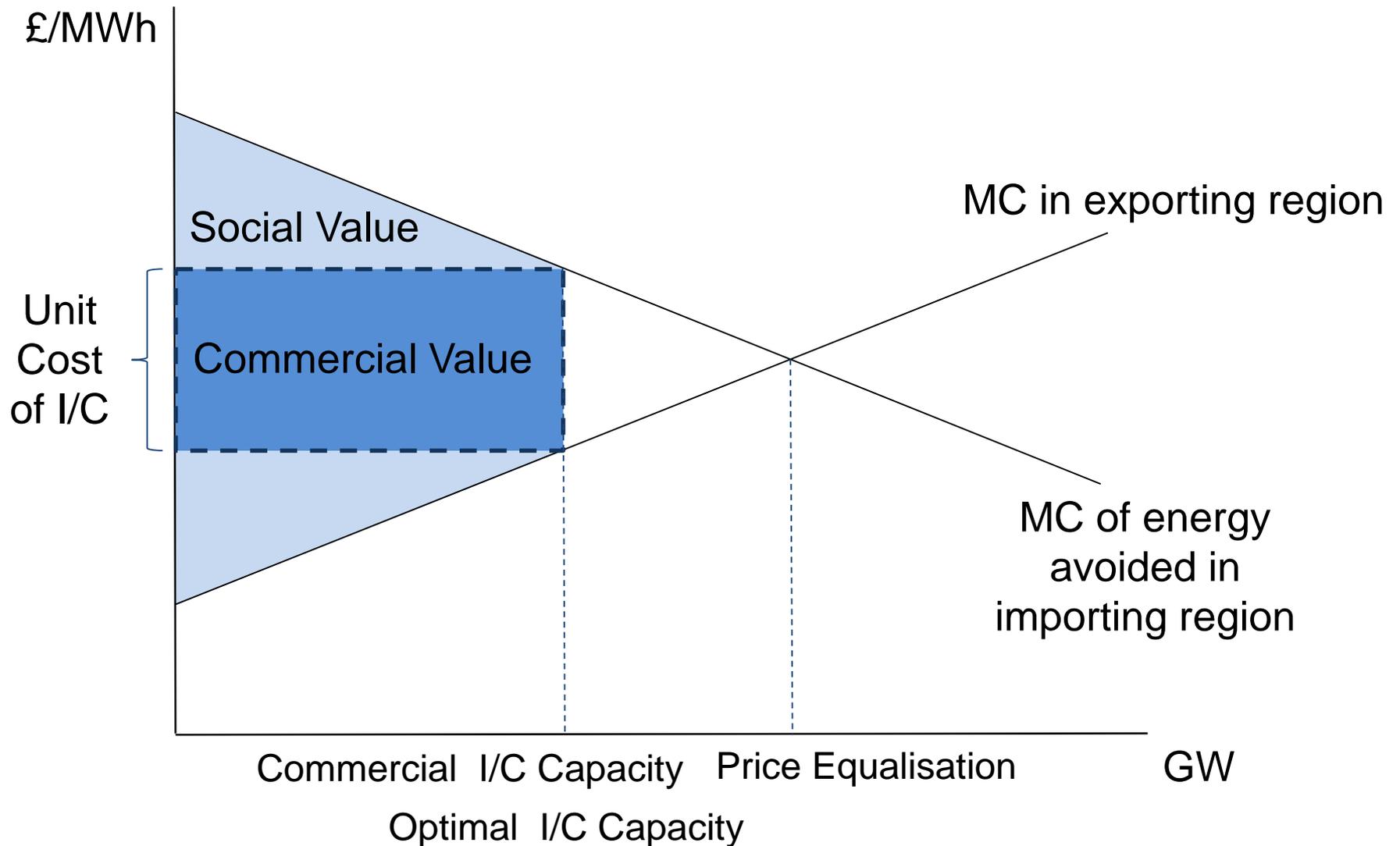
GW of storage



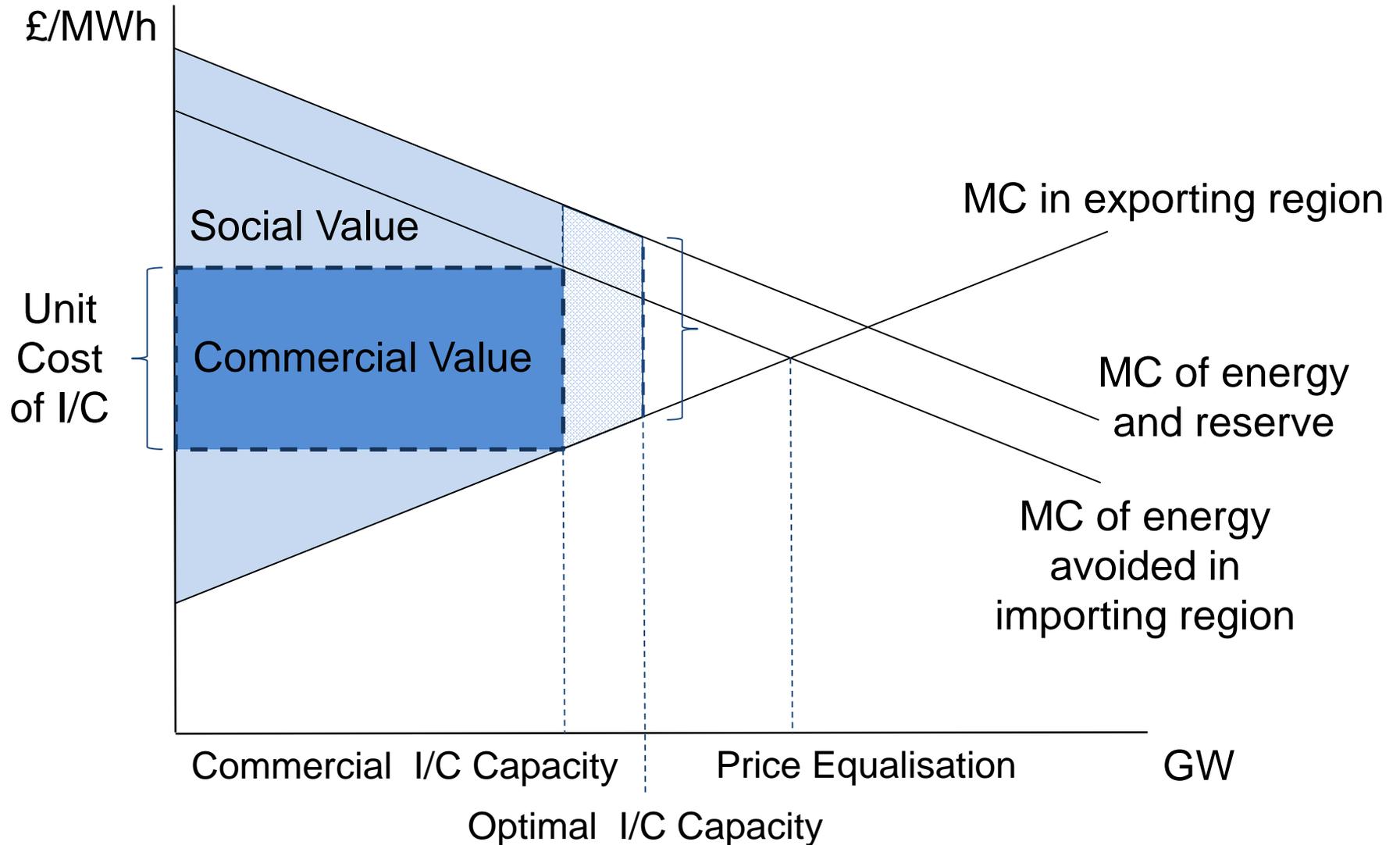
**Do we pay enough for
flexibility?**



Interconnector Economics



Interconnectors with Reserve





The need to multi-task



System Value of Energy Storage

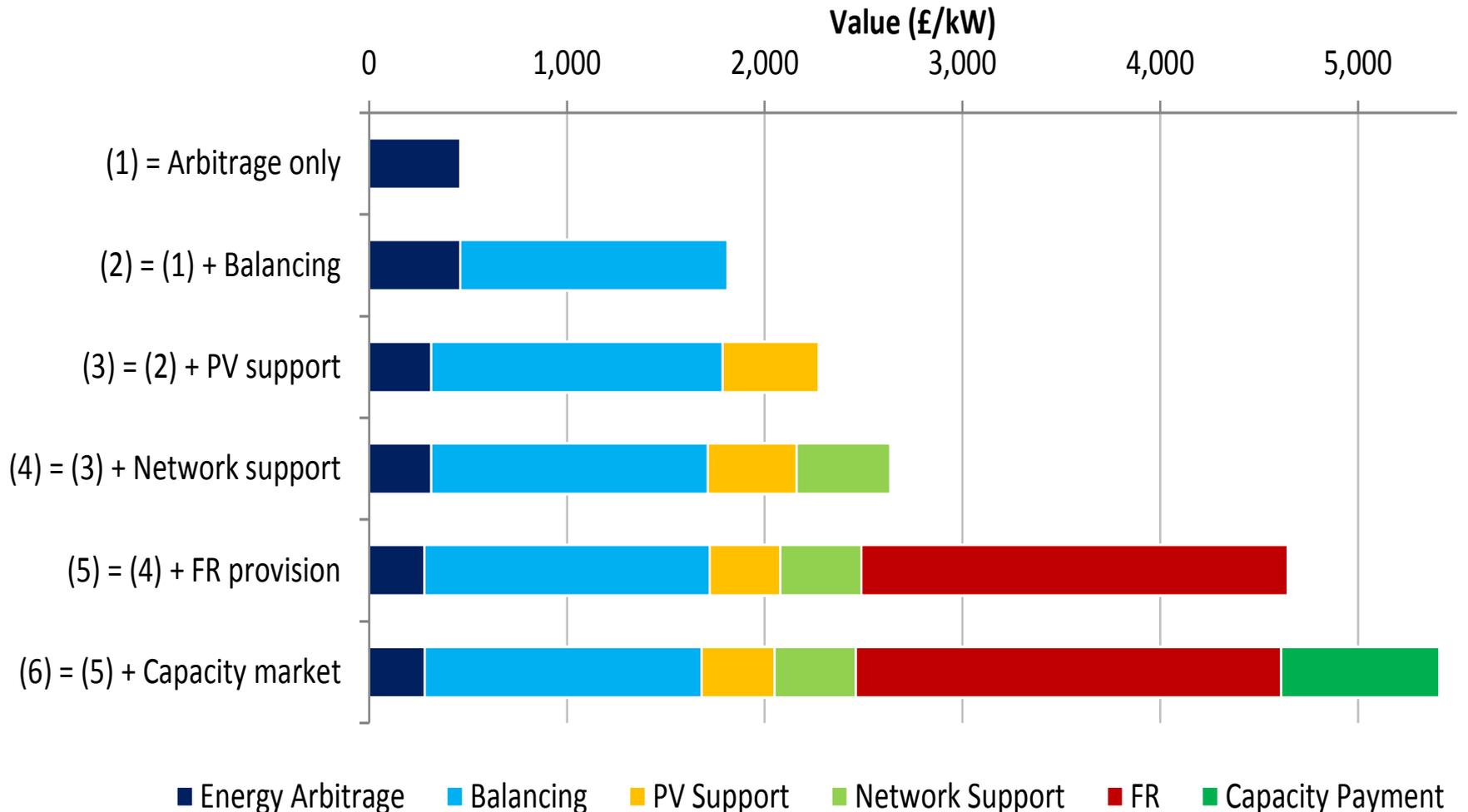
Modelling by Goran Strbac

- **Arbitrage**
 - ✓ Participate in day-ahead energy market
- **Balancing services**
 - ✓ Participate in real-time balancing market
- **Network Support**
 - ✓ Reducing need for T & D network reinforcements
- **Frequency regulation services**
 - ✓ Providing primary/secondary / tertiary frequency regulation services
- **Capacity market**
 - ✓ Contributing to meeting peak demand, reducing need for peaking plant

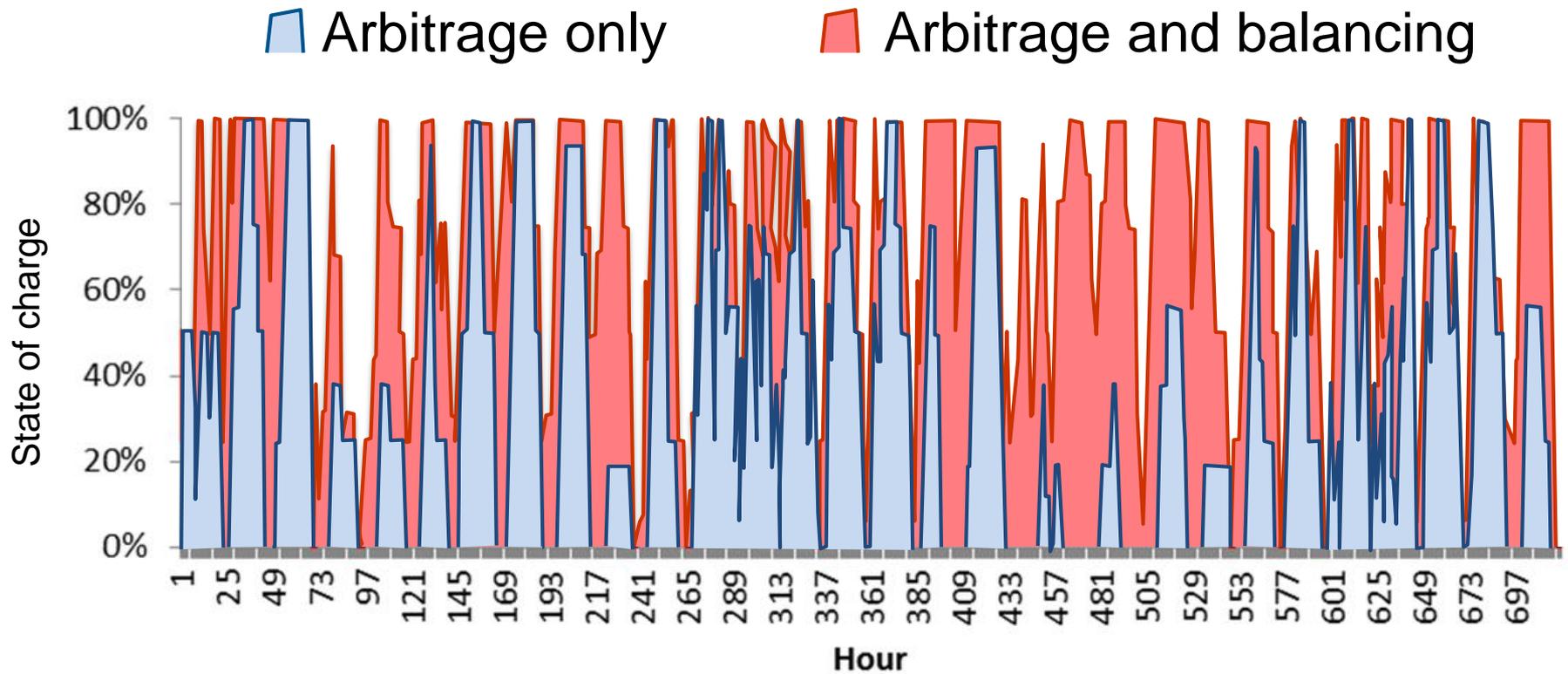


System Value of Energy Storage

Modelling by Goran Strbac



It's profitable to be charged more





Getting the right incentives

Multi-product auction design

- What's the right mix of fast and slow response to buy?
 - How valuable is each type?
 - What is on offer?
- Greve and Pollitt suggest a Vickrey-Clark-Groves auction
 - System operator calculates the value of each combination
 - Chooses combination that maximises value minus bid
 - Pays selected providers their contribution towards maximised social value
 - Value with that provider, minus value without
 - Incentive compatible – best to bid your true cost!



Thank you