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Imperial means Intelligent Business

The Economics of Flexibility

Richard Green

This is the web version of my talk, with notes added in bubbles that should be visible if you run the mouse over them.

14 February 2020

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What is flexibility?

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

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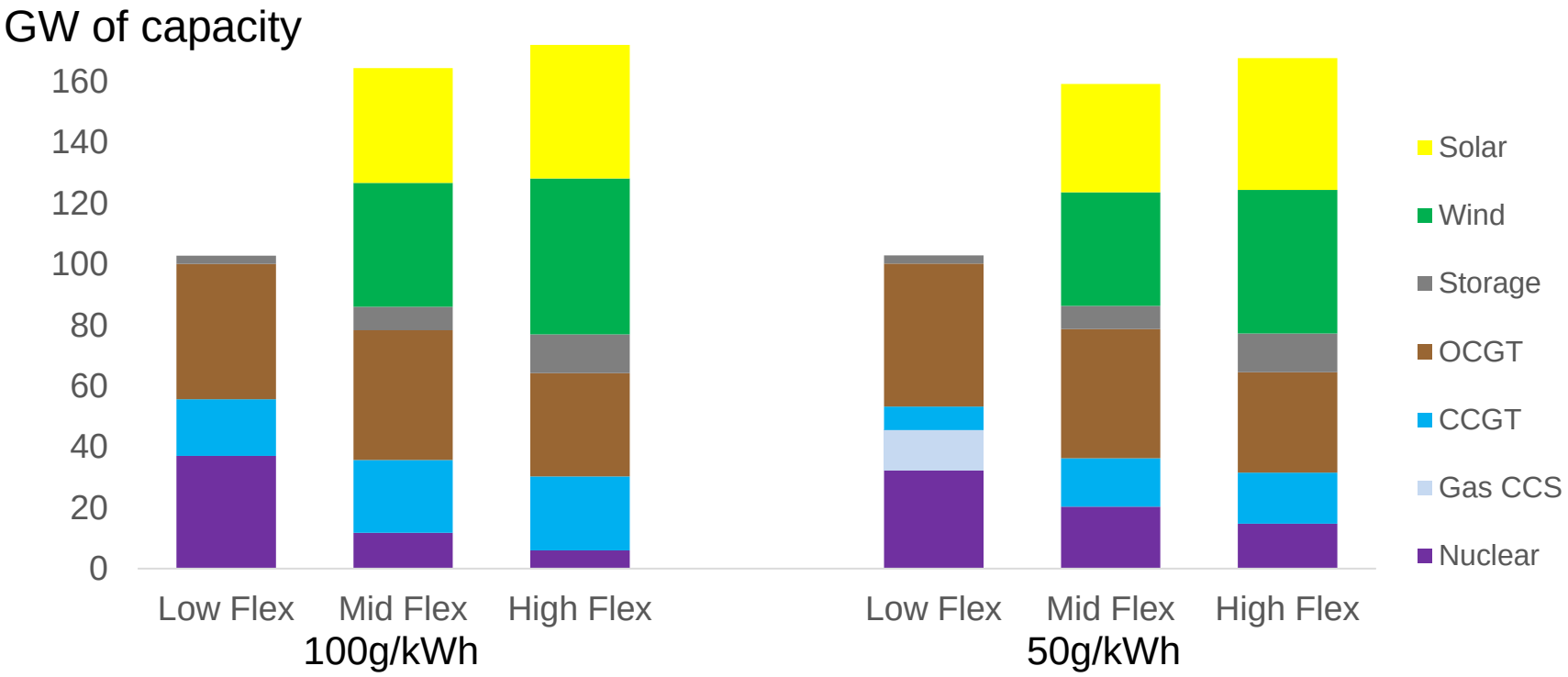
Does it matter?

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



Strbac *et al.* (2016) for National Infrastructure Commission

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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?

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Constrained Optimisation

(making the power system work)

- Generation = Demand + Losses
  + net Storage + net Exports
- Line Flows ≤ 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

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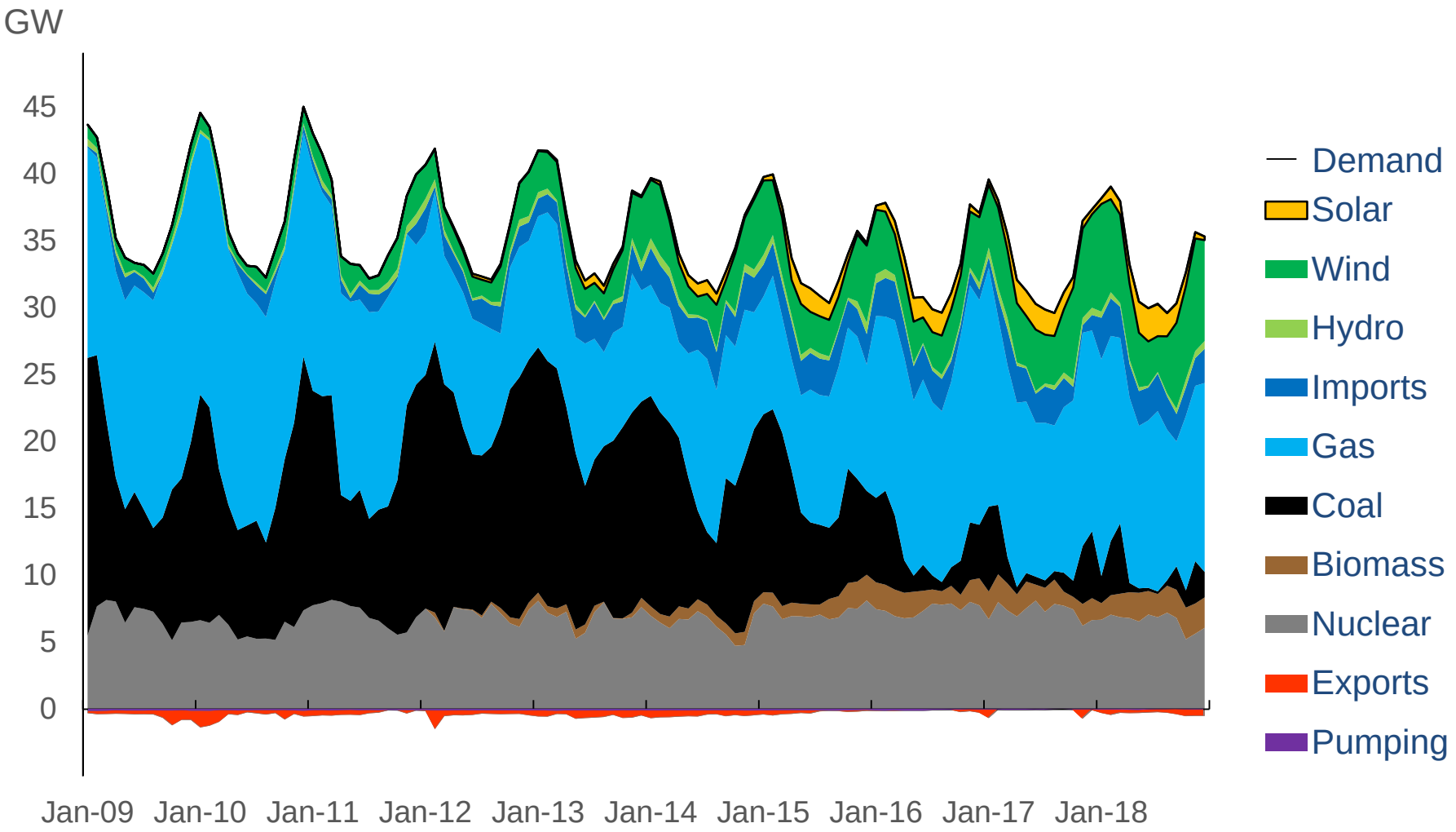
Generation in Great Britain

Monthly averages



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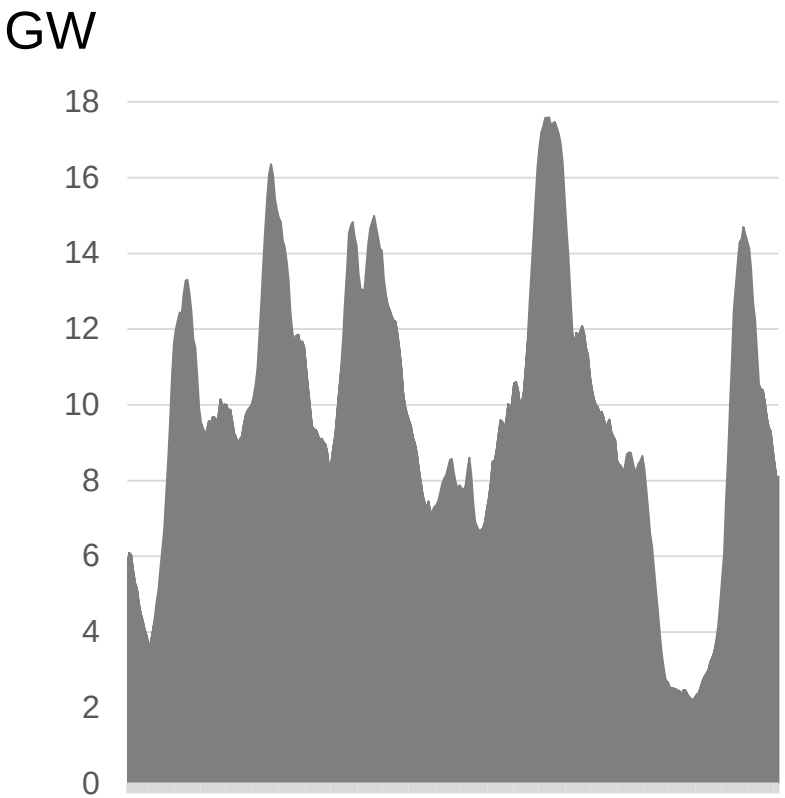
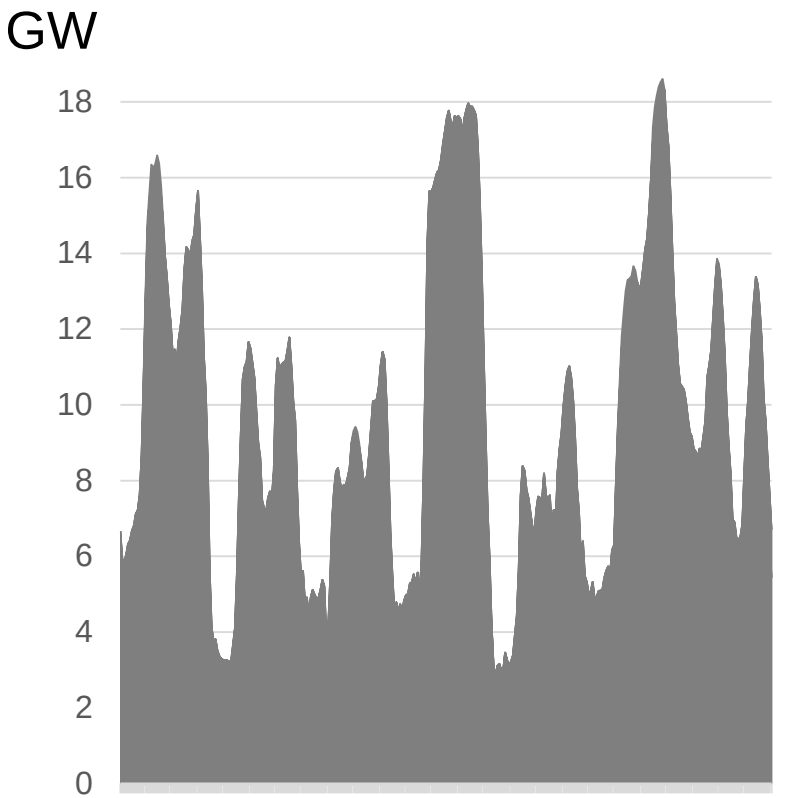
Variable Generators

Coal, Gas and Oil, versus Wind and Solar





Source: Electric Insights (data are for GB)

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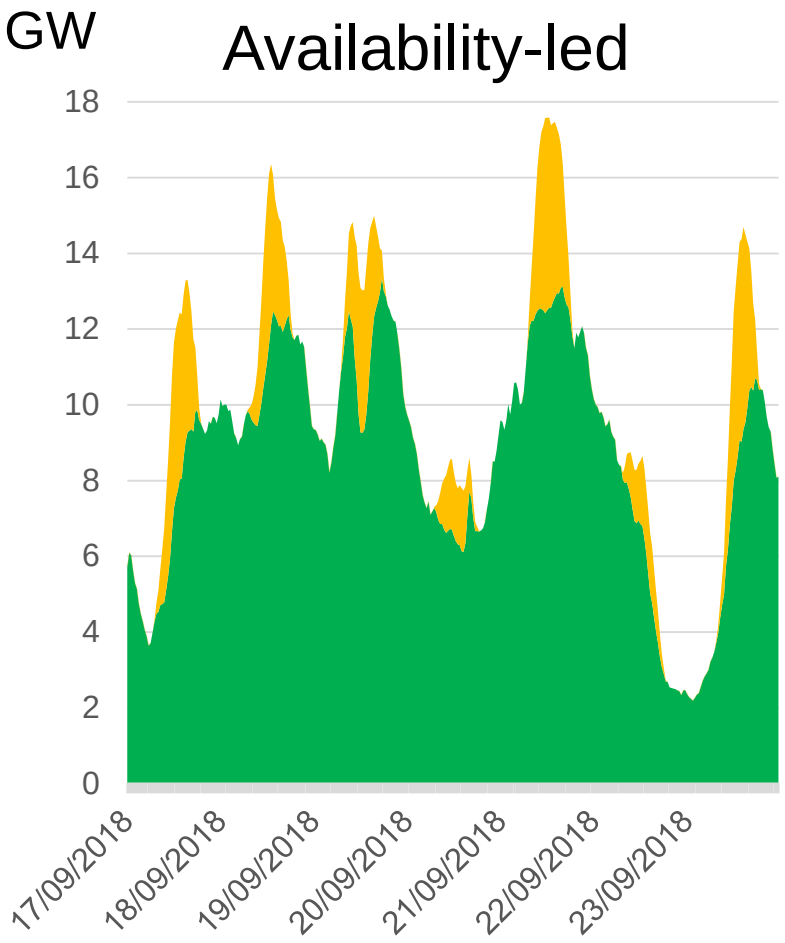
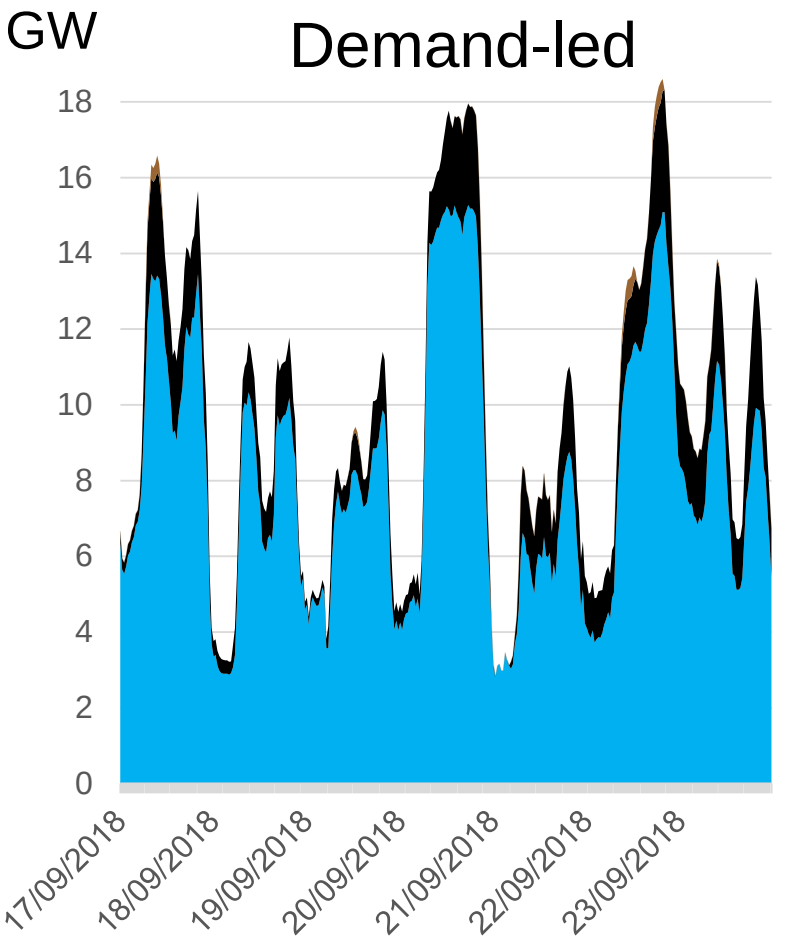
Variable Generators (x2)

Wind and Solar versus Coal, Gas and Oil





Source: Electric Insights (data are for GB)

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 price of flexibility

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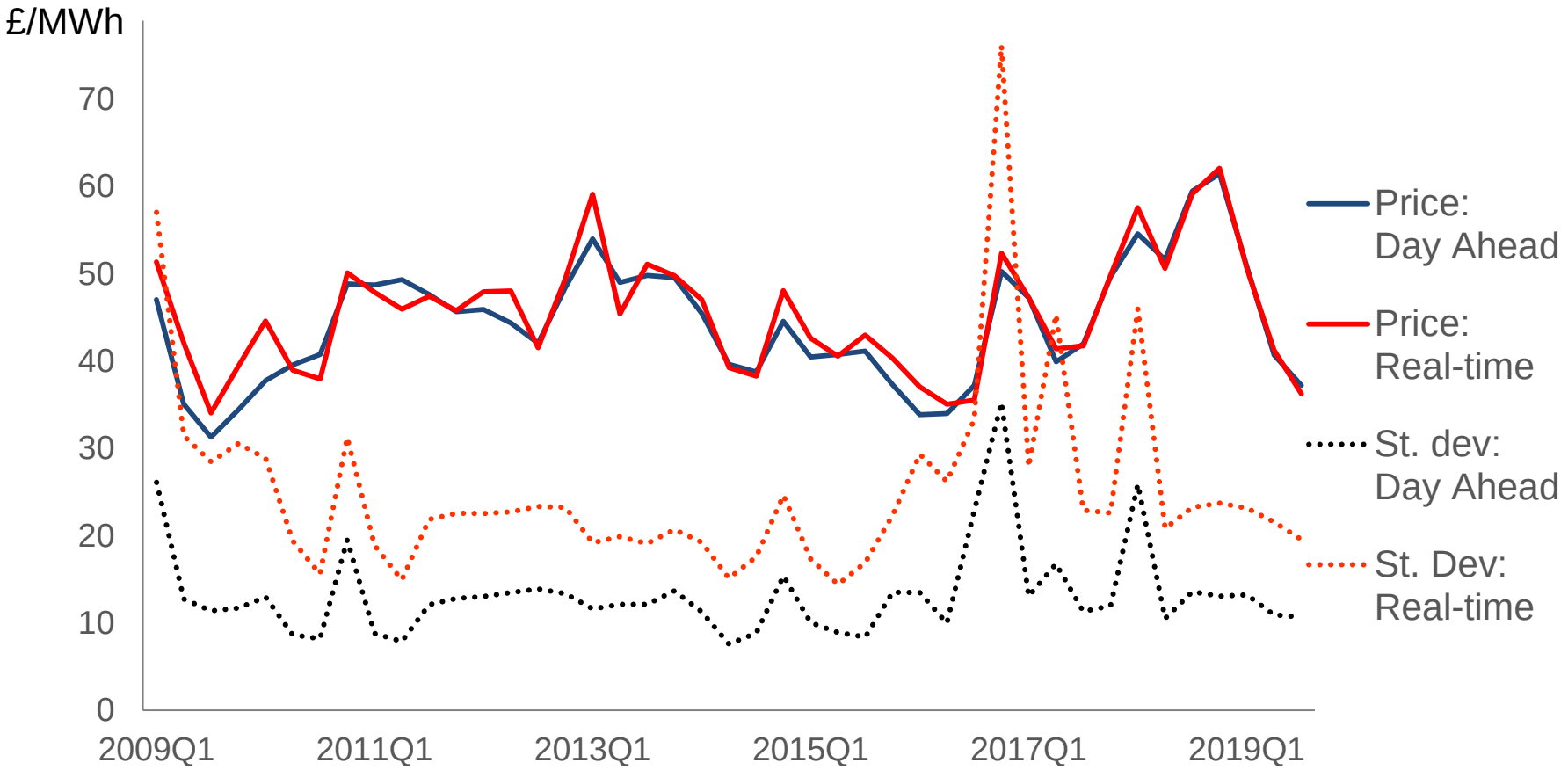
Day-ahead and Real-time Prices

GB data, quarterly averages



When does “free” electricity mean higher prices?

When the system’s not flexible…

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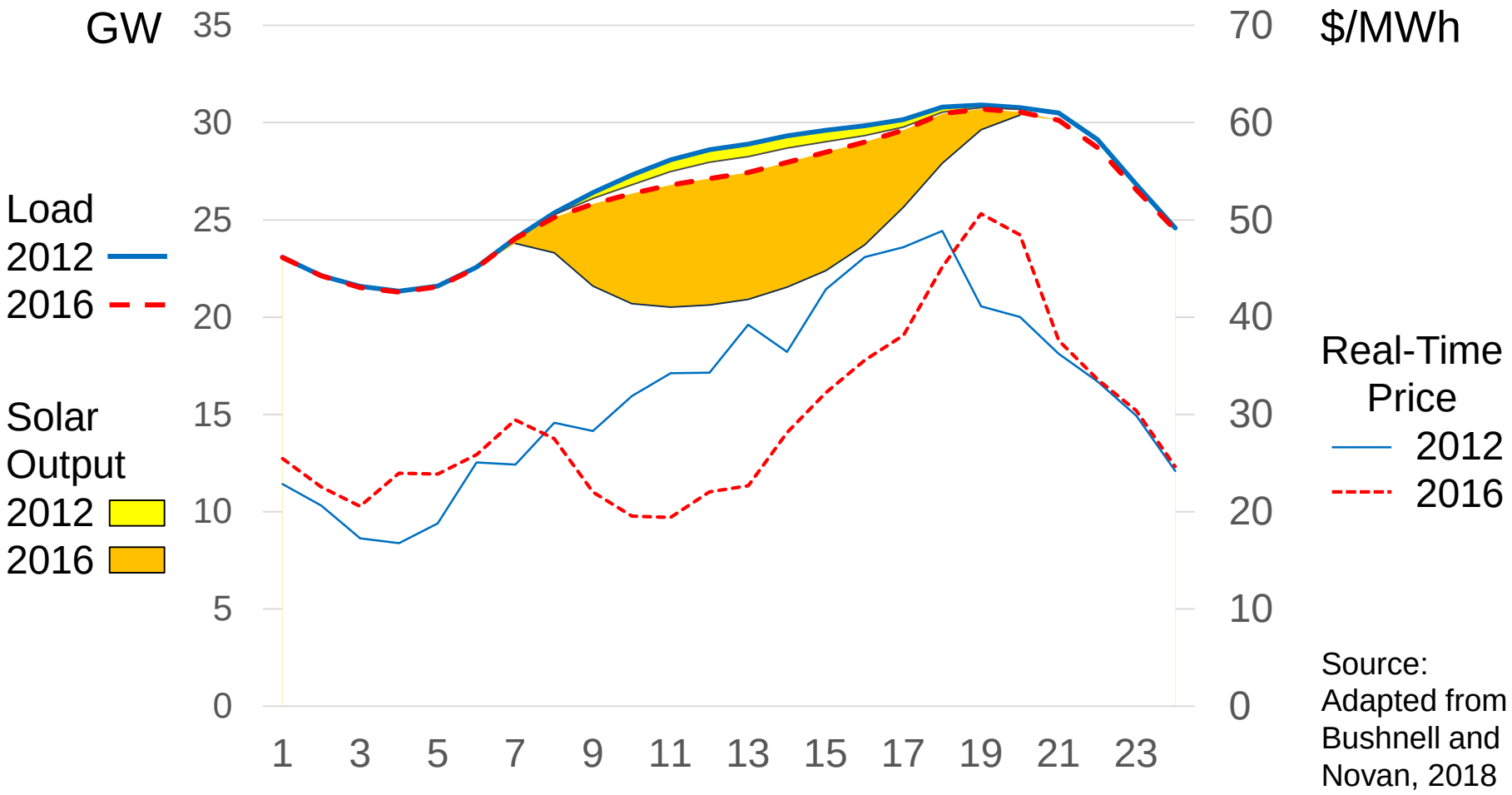
Load, PV Output and Prices

California, 2012 and 2016



Source: Adapted from Bushnell and Novan, 2018

See also Hirth (2015) http://dx.doi.org/10.1049/iet-rpg.2014.0101

Could free power be too expensive to use?

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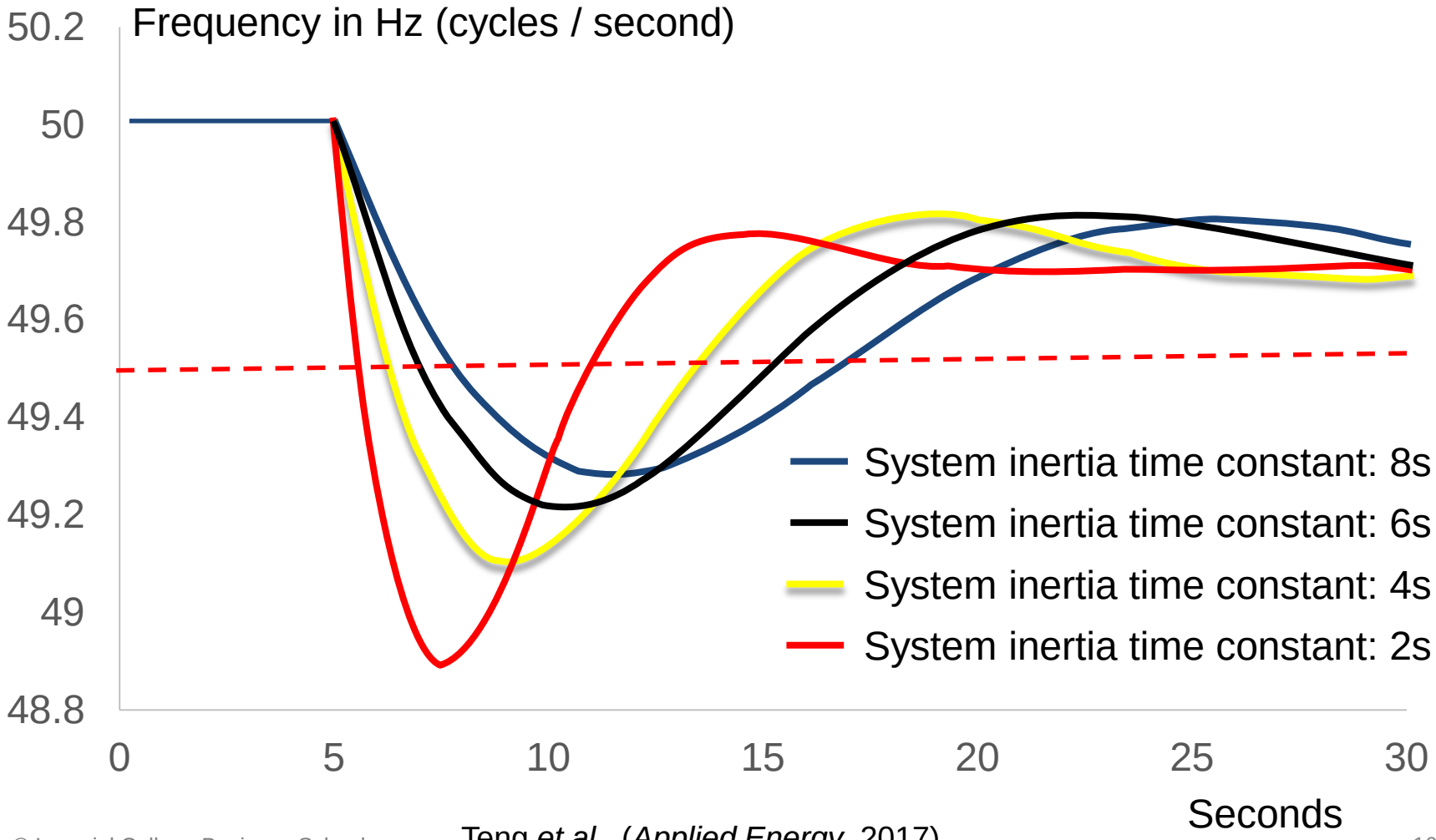
The importance of inertia

Post-fault system frequency



Teng *et al.*, (*Applied Energy*, 2017)

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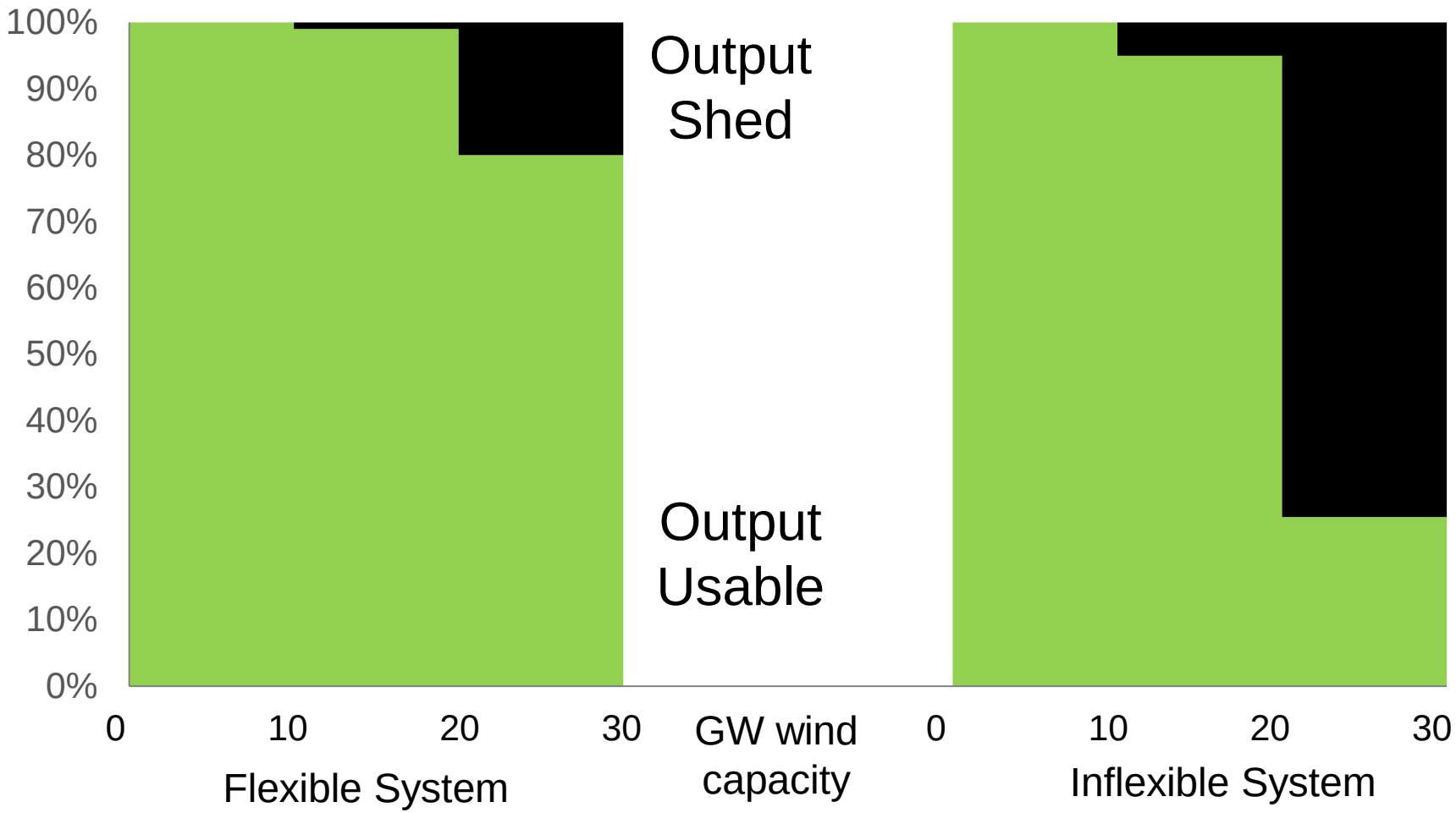
Acceptable wind output

System may not be able to absorb it



Strbac *et al.*, 2016

Efficiency & Environment, Infrastructure, Technology

National Grid awards £328m contracts to manage stability of electricity grid

This new approach is expected to save consumers up to £128m over the six-year period

Contracts with 5 providers at 7 sites, giving 12.5 GVA.s of inertia

The value of flexibility will rise over time

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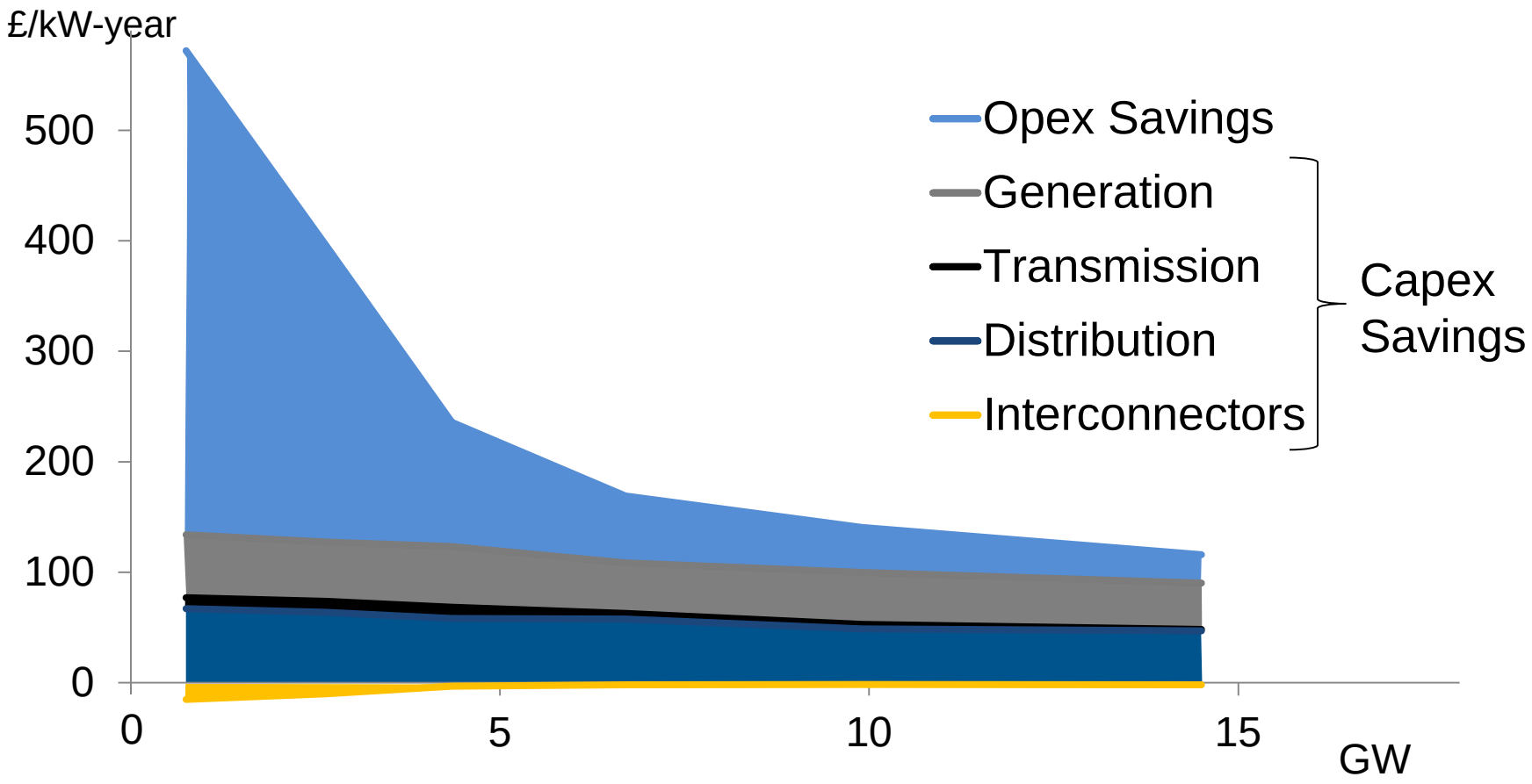
Marginal Value of Storage

(Strbac *et al.*, 2012)



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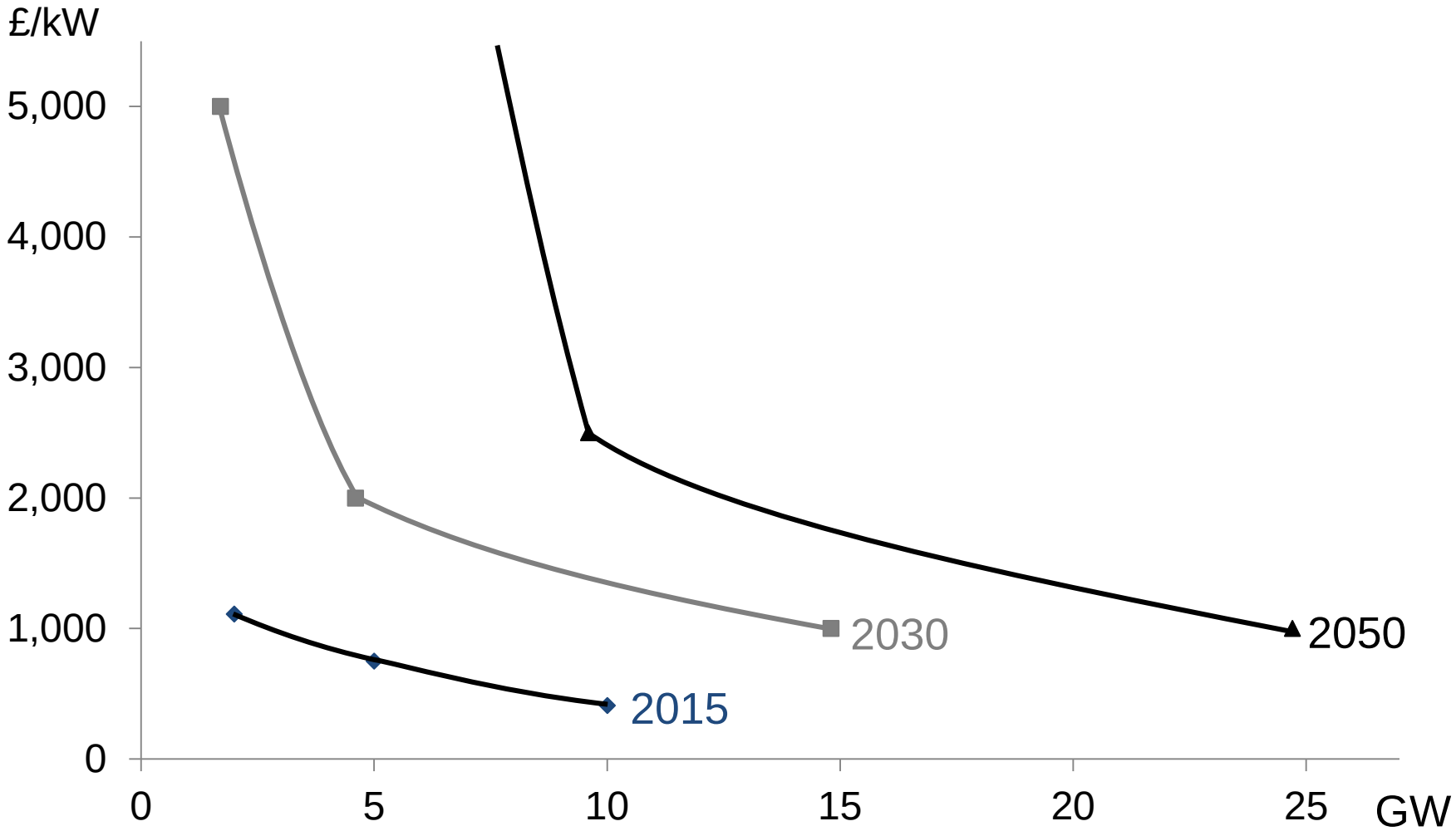
The value of storage over time



The value of flexibility sources depends on what else is available

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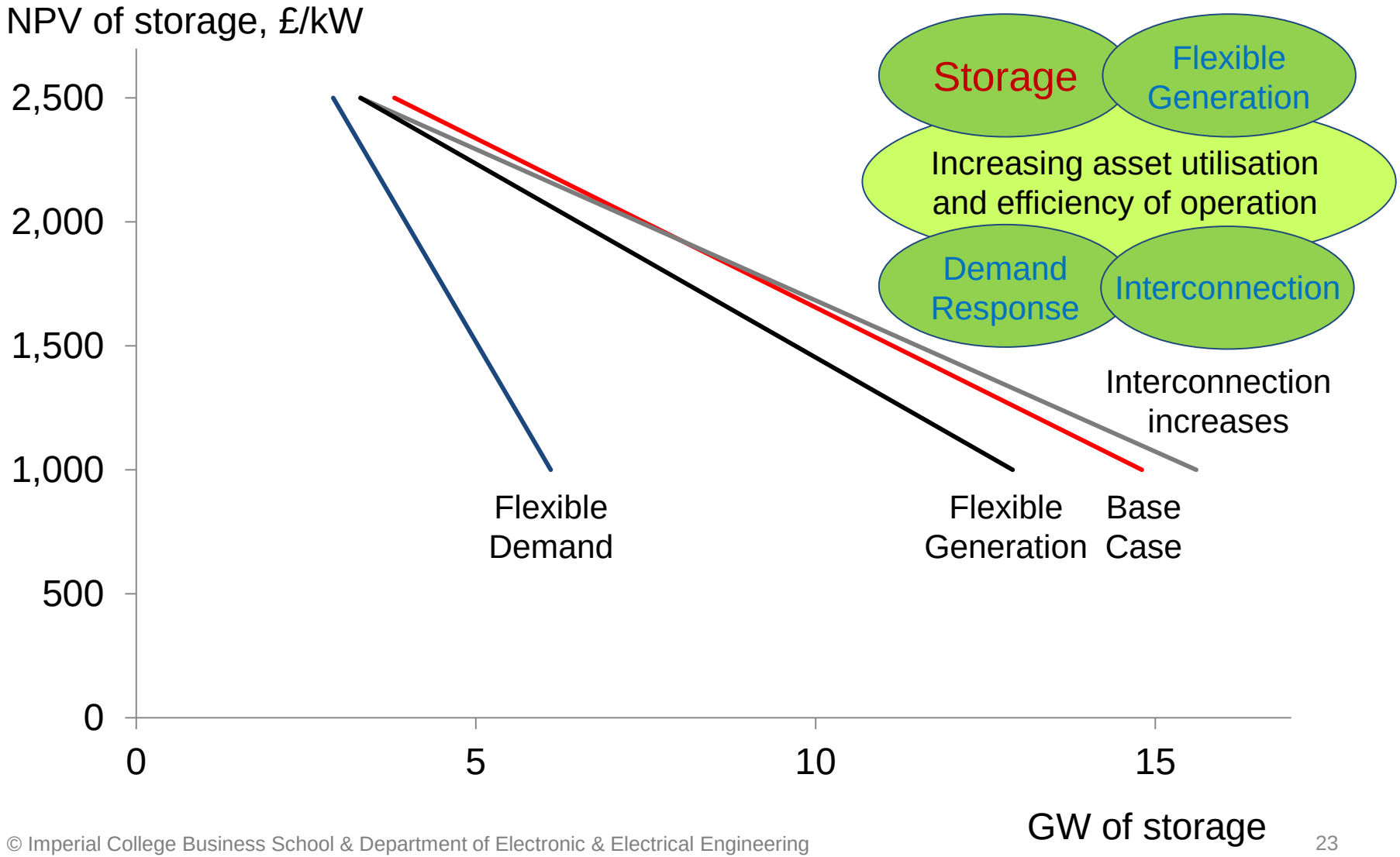
Any substitutes for storage?



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The need to multi-task

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System Value of Energy Storage

- **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

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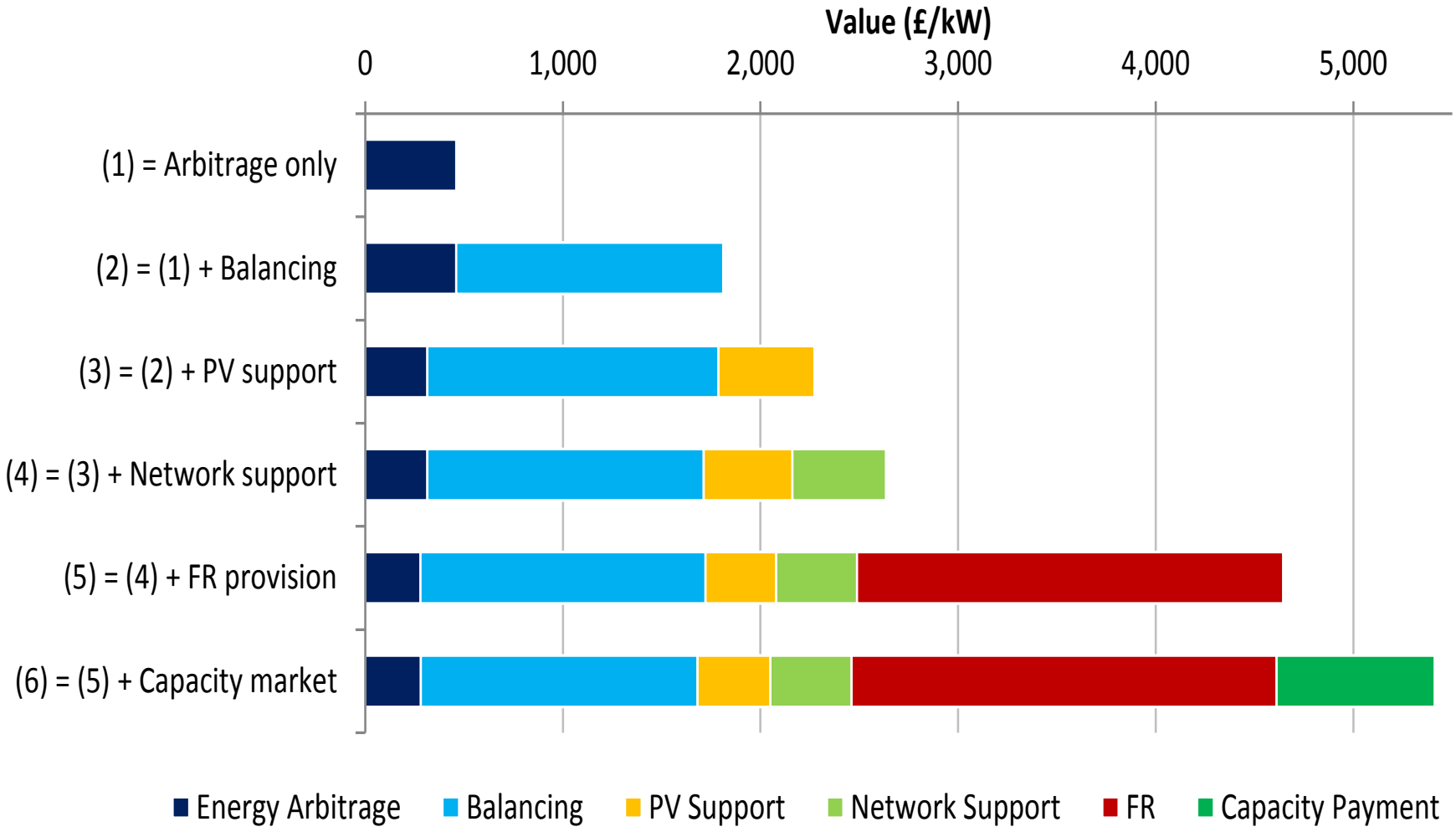
System Value of Energy Storage



Strbac *et al.* (2017), htpp://dx.doi.org/10.1109/MPE.2017.2708858

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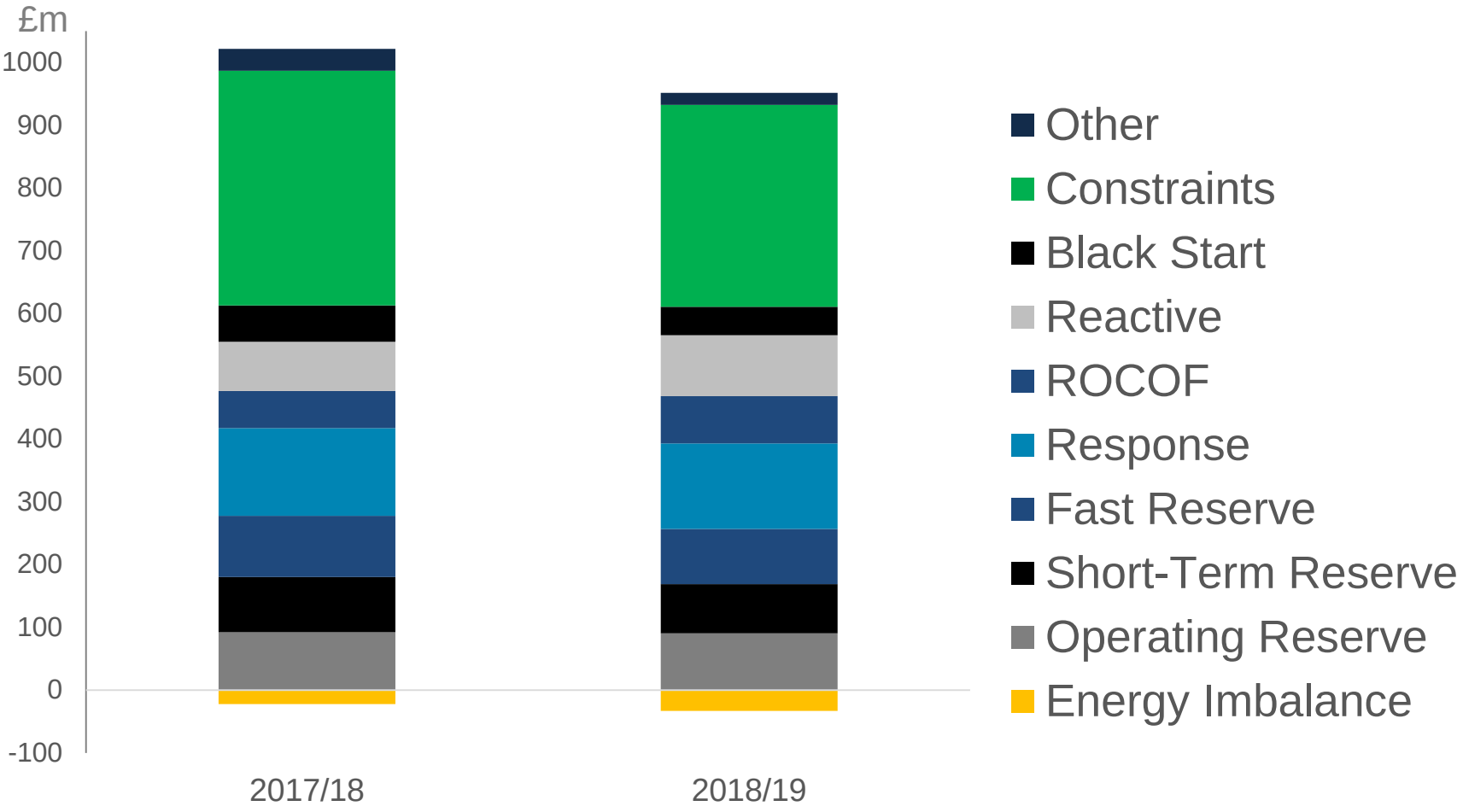
Balancing Great Britain

National Grid Costs, financial years



Source: National Grid ESO

Getting the right incentives

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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!

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Do we pay enough for flexibility?

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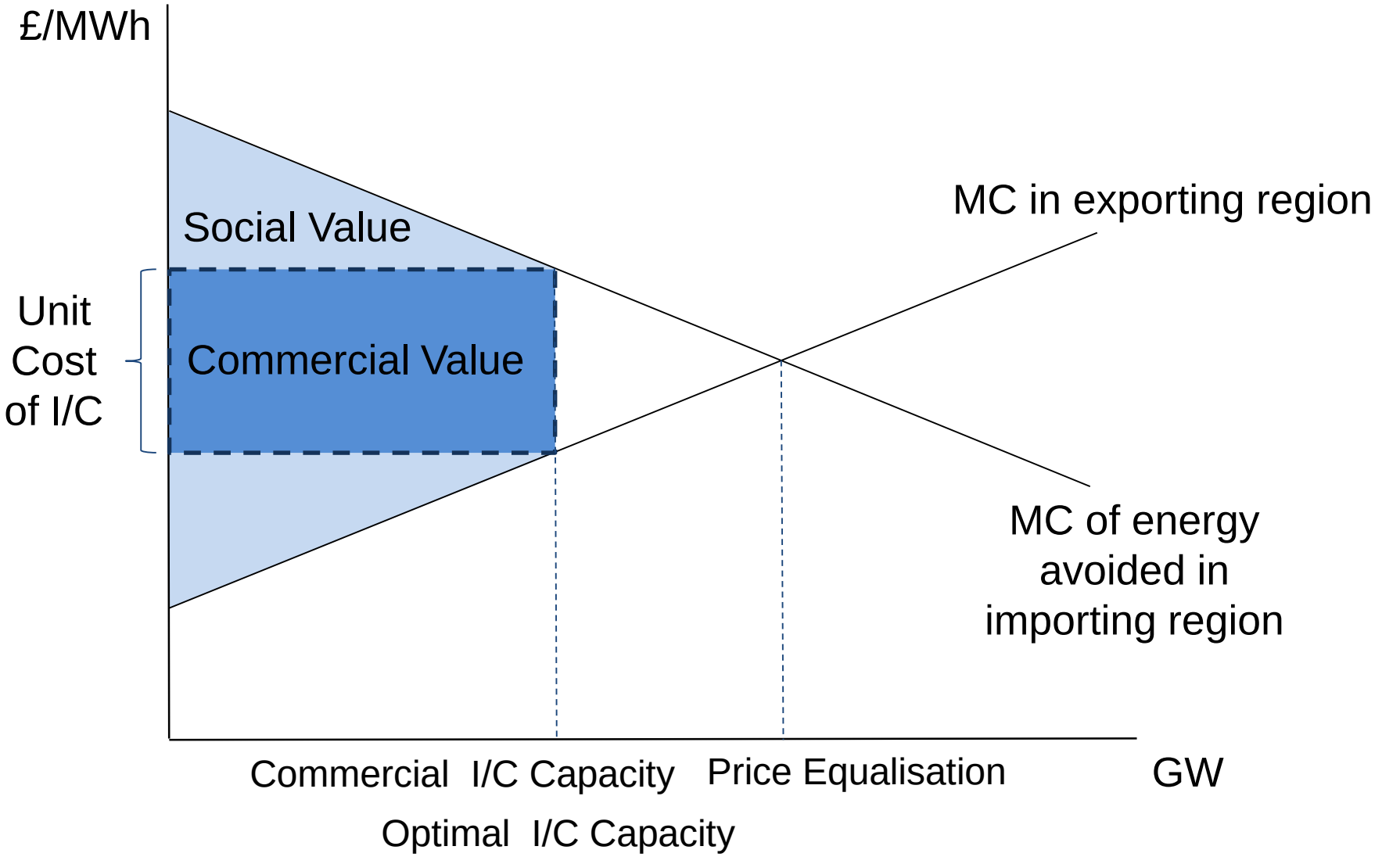
Interconnector Economics



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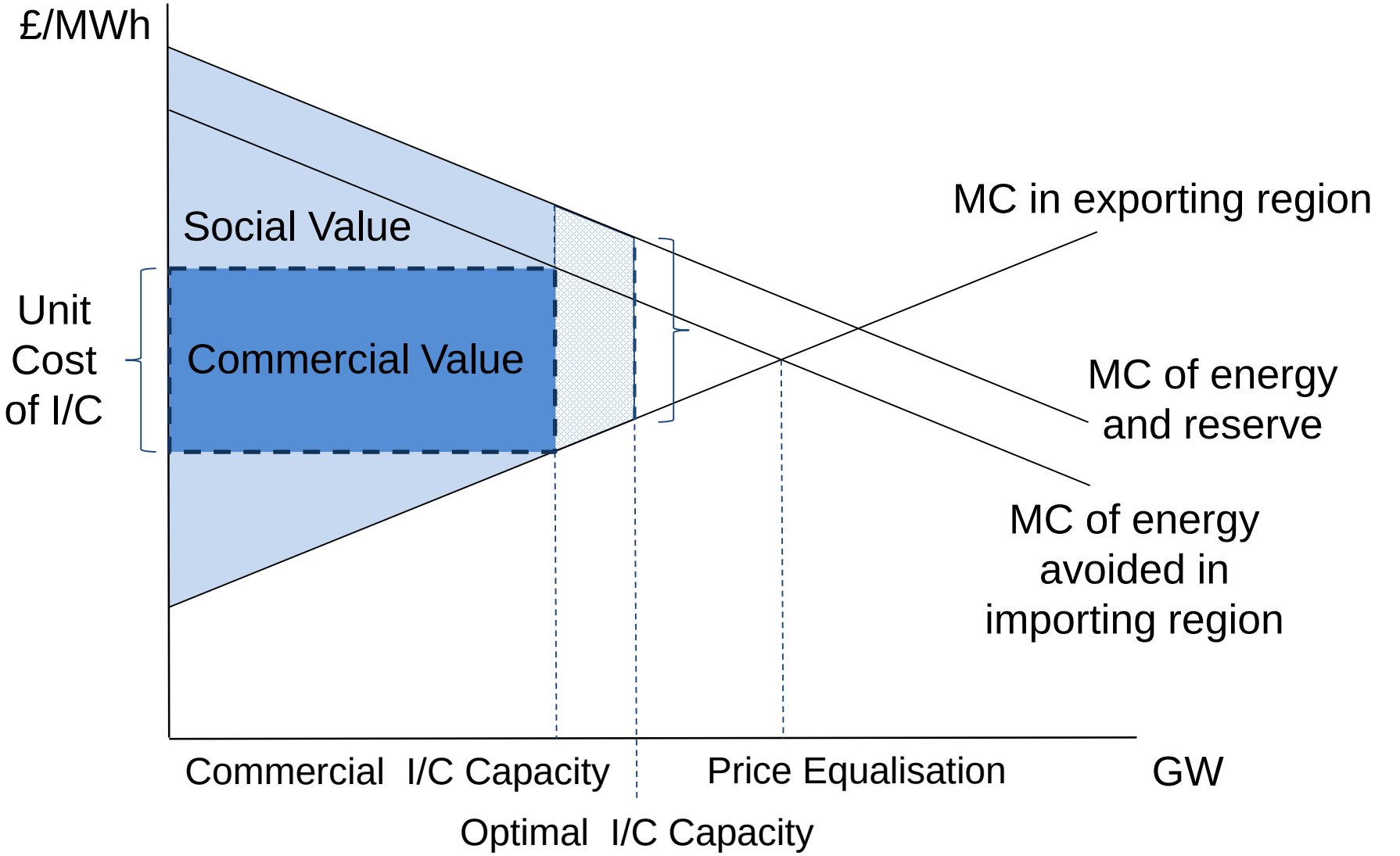
Interconnectors with Reserve



Thank you