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System integration of low-carbon generation in future energy systems

Role of flexibility in supporting cost-efficient transition to low-carbon future

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Whole-system modelling critical for capturing Time and Location interactions in low carbon systems

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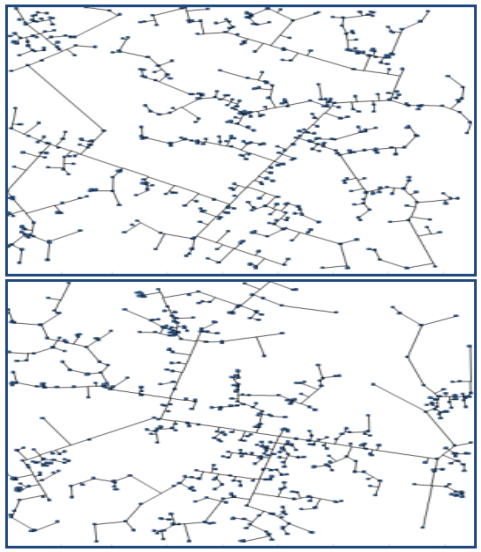
Local district level Infrastructure



Demand-Side Response

Flexible Generation

Increasing asset utilisation and efficiency of system balancing

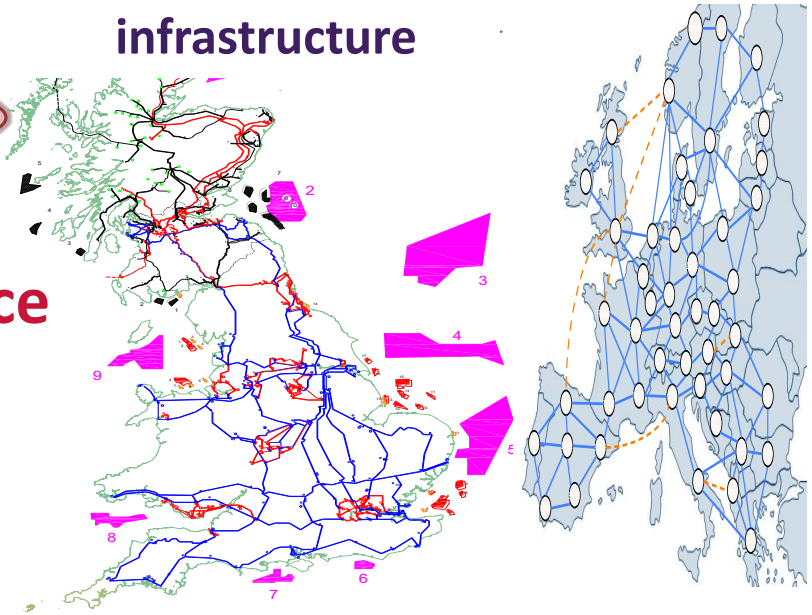
Network

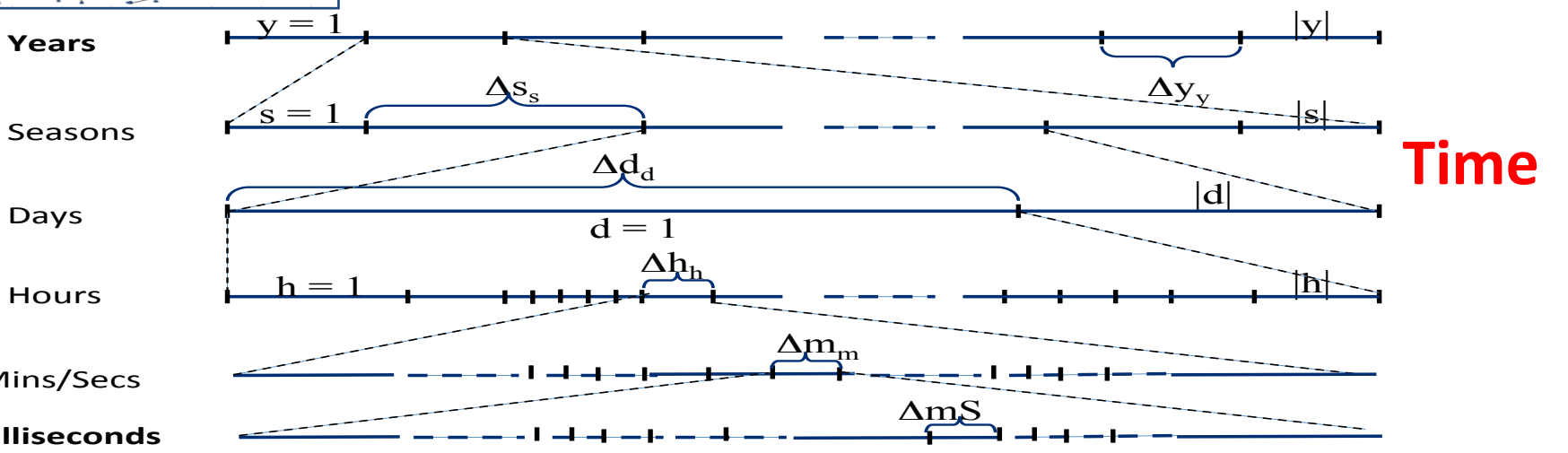
Storage

Integrated Local & International Infrastructure

Space

National / EU level infrastructure





Time

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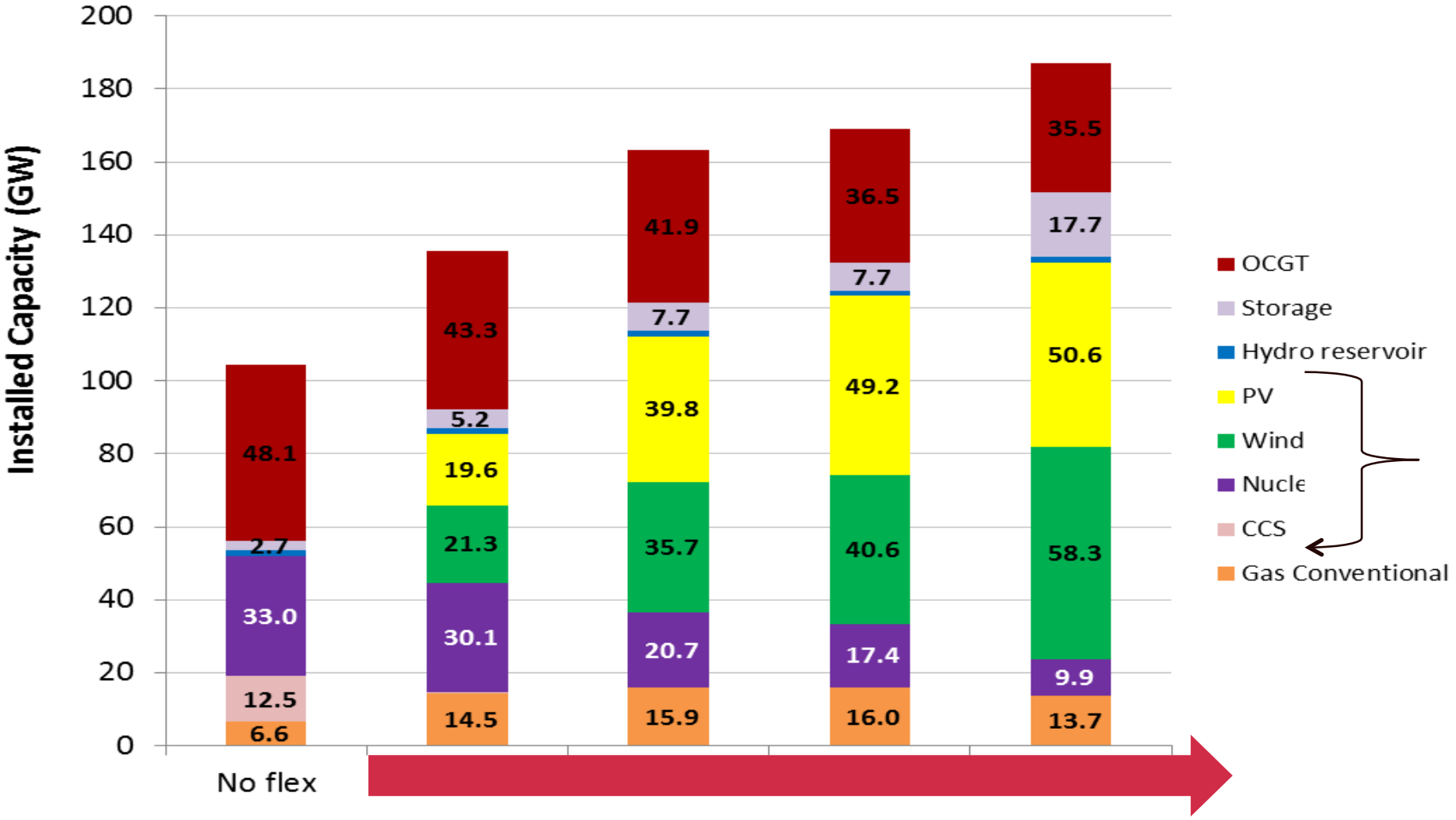
Flexibility – drives generation portfolio



Flexibility –Storage and flexible demand

Coordinated whole-energy / multi-vector approach to decarbonization

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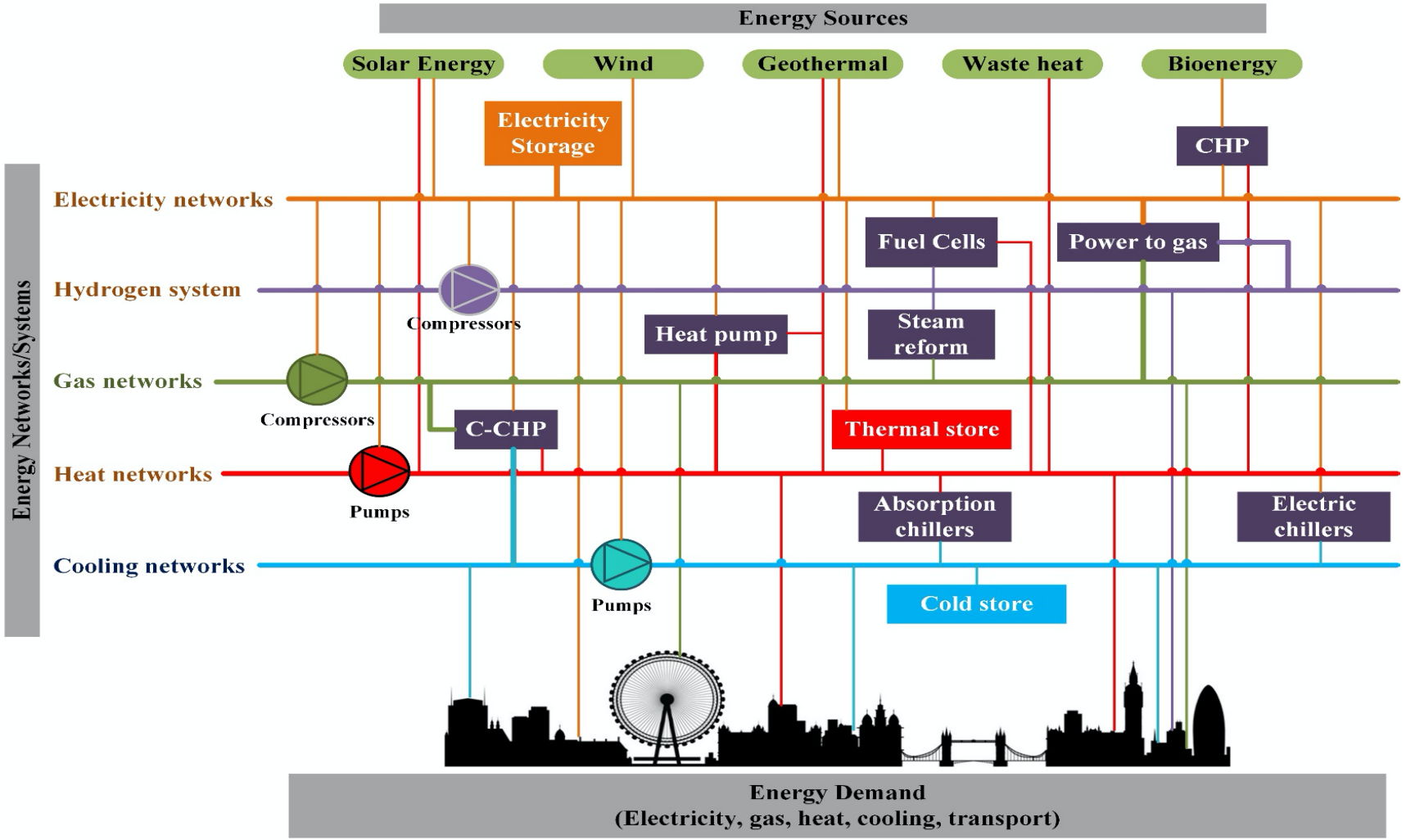

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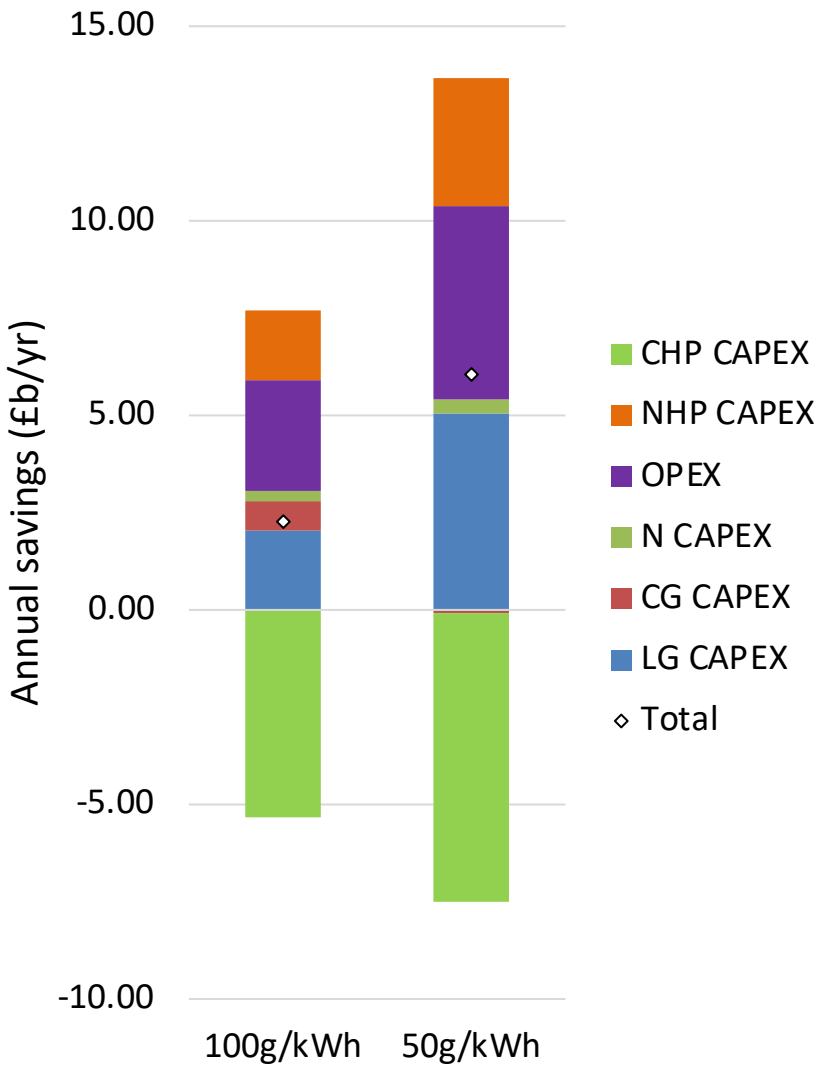
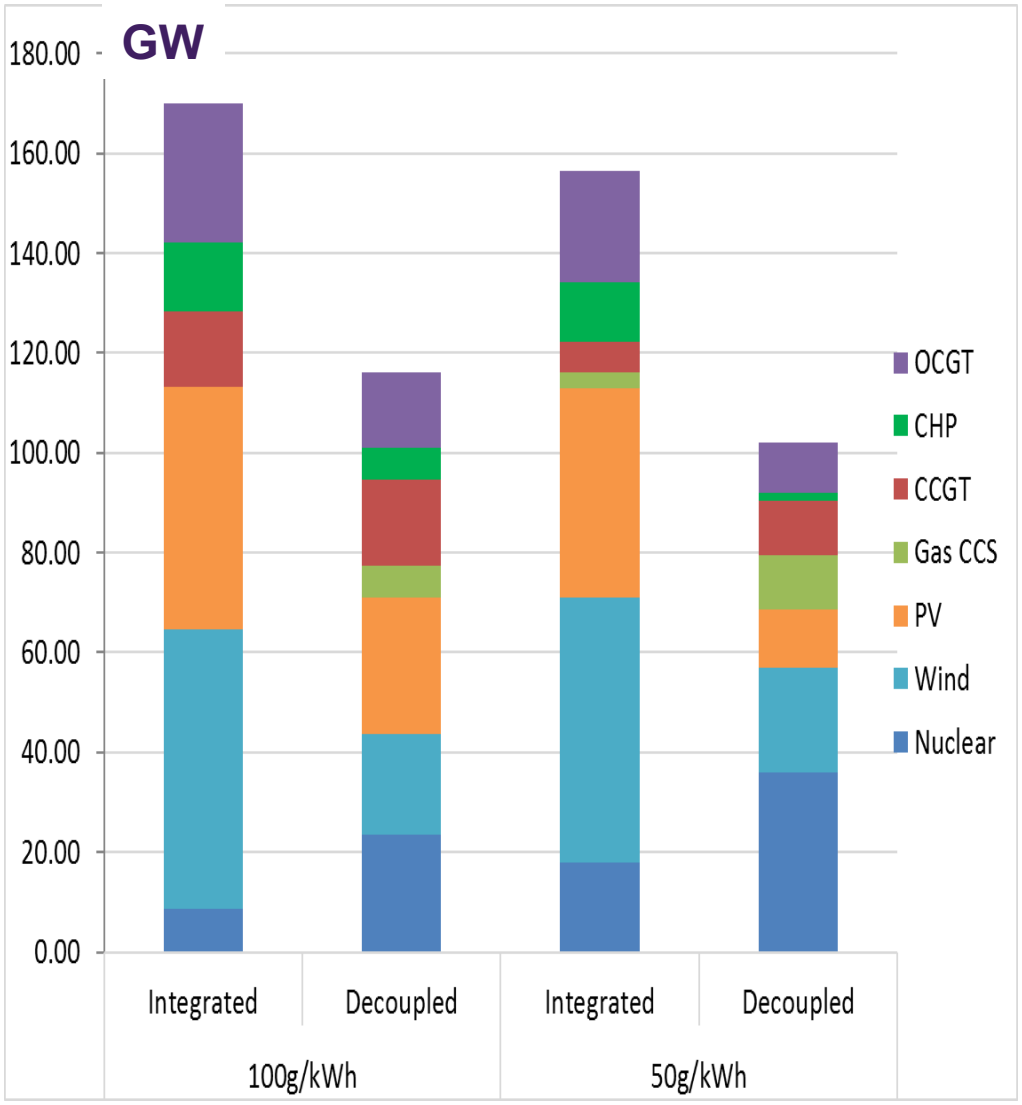
Significant savings from integrating electricity and heat systems





Optimal generation portfolio is dependent on cross-vector flexibility

Silo vs integrated H_2 and electricity: impact on electricity demand and supply

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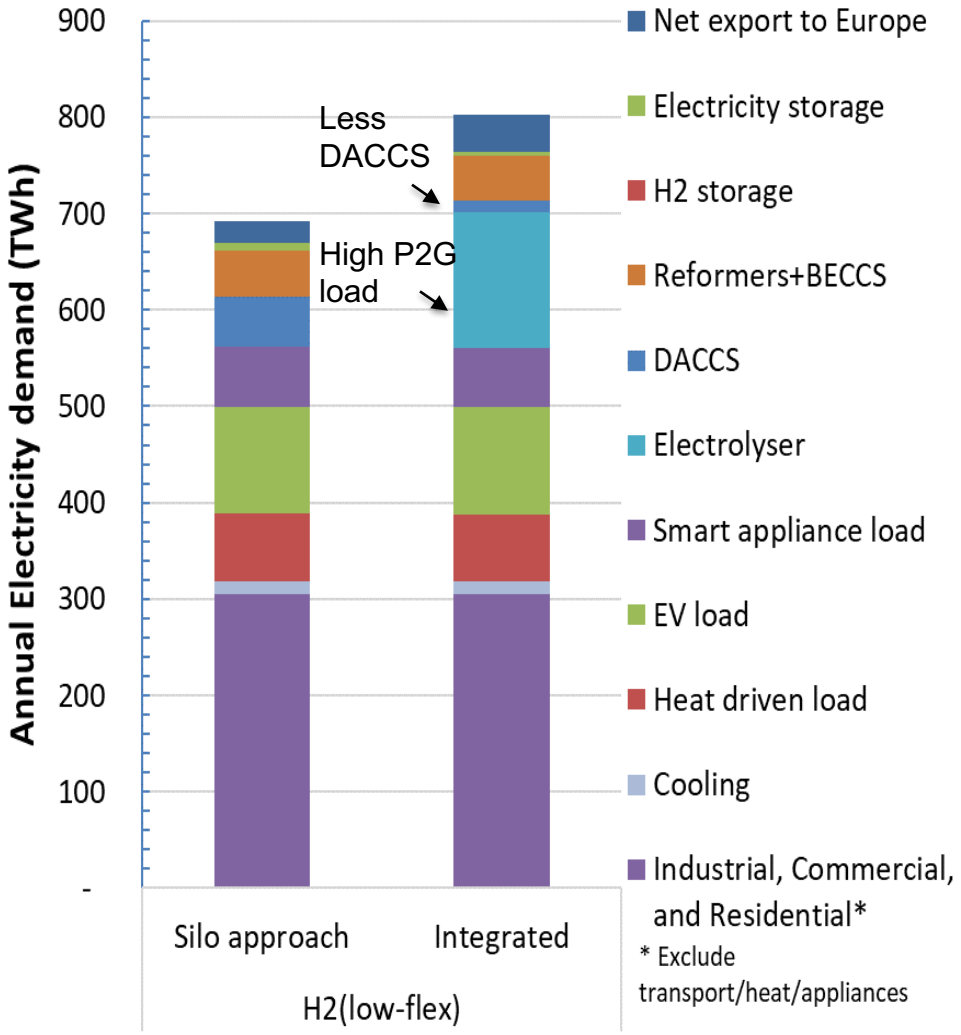

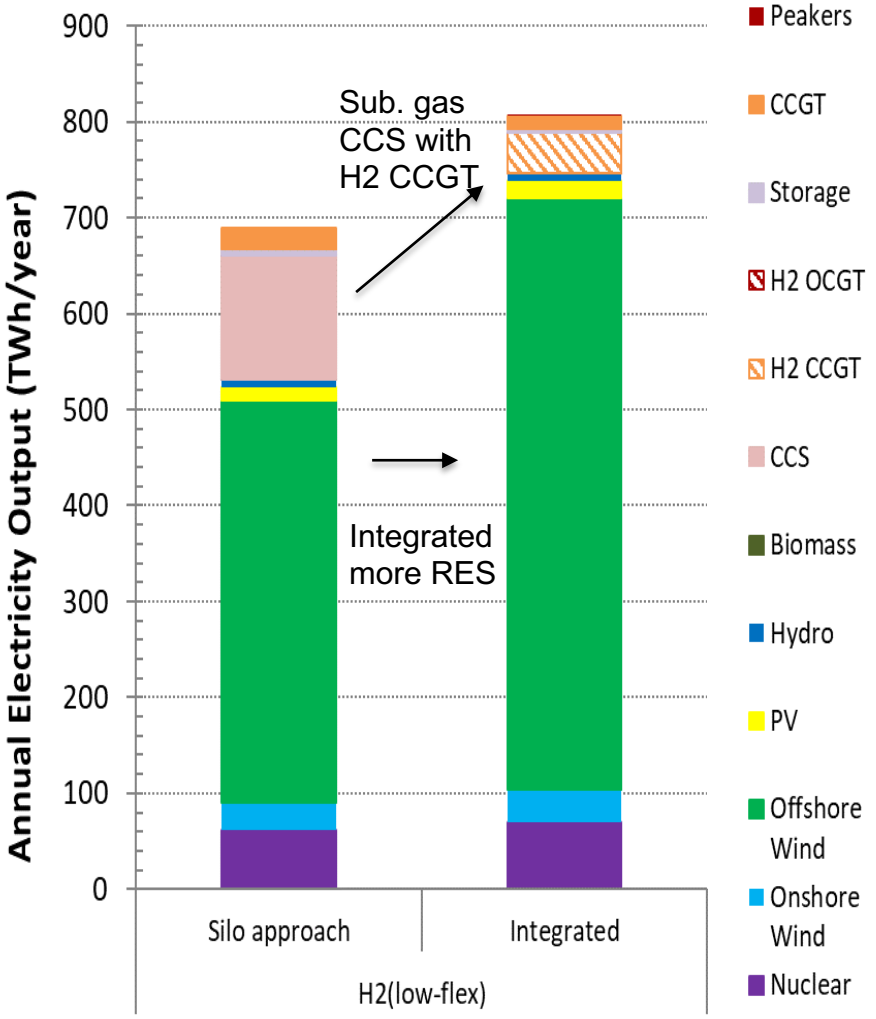

Saving from integrated approach: £5.6bn/year

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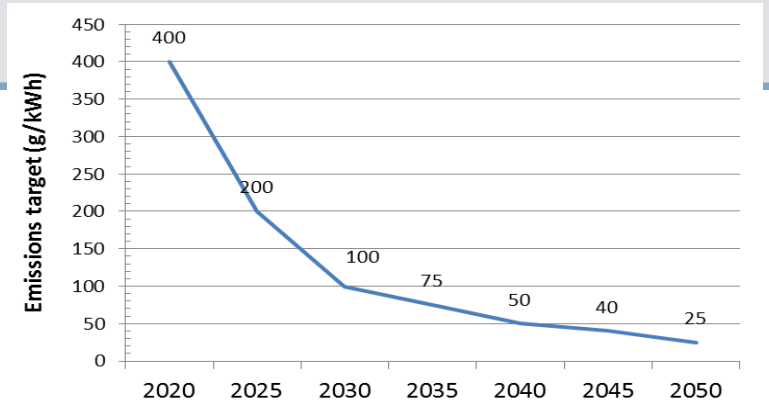
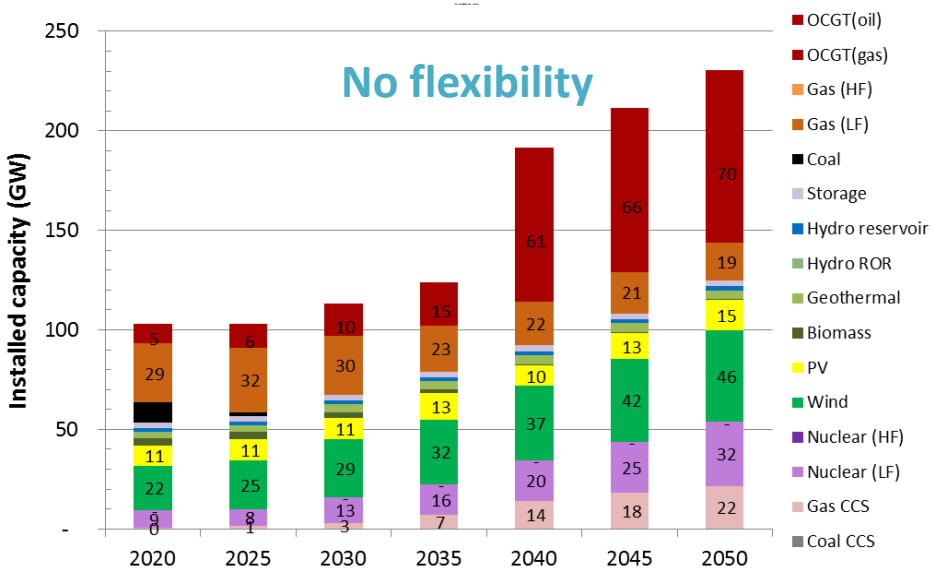
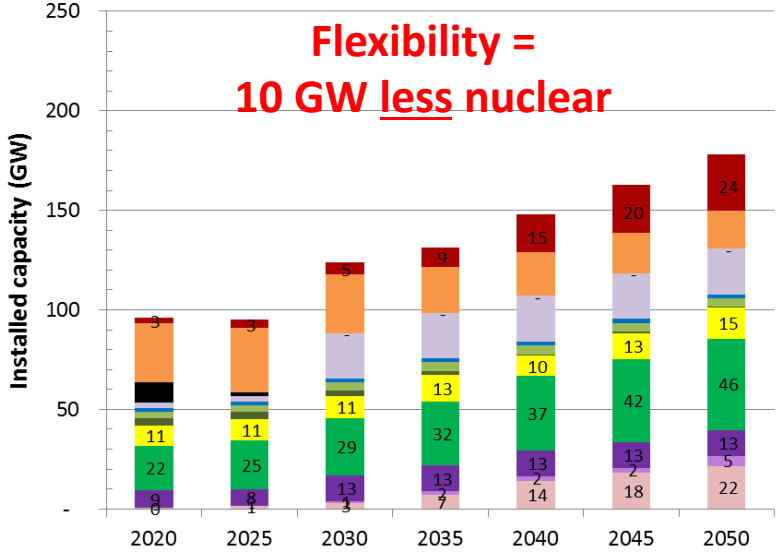
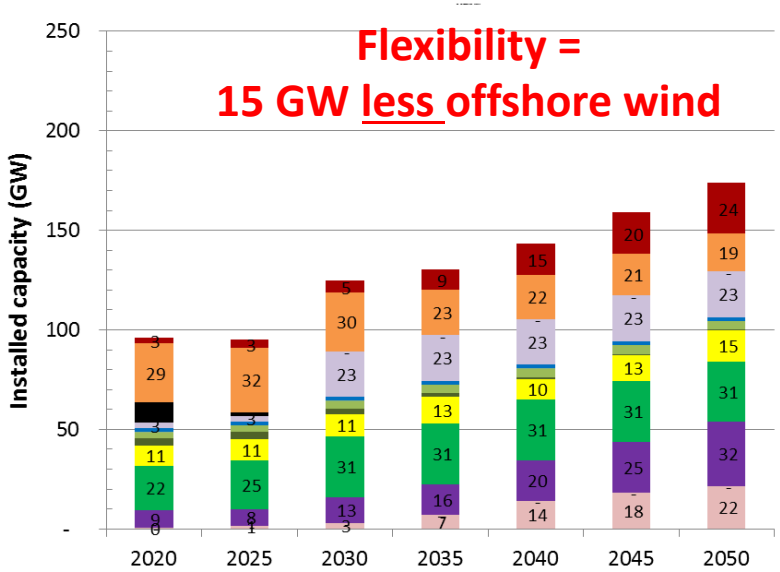
Carbon benefits of flexibility





UK scenario





Volume of the market for **flexible technologies & smart control** post 2030 in **UK > £8bn/y**

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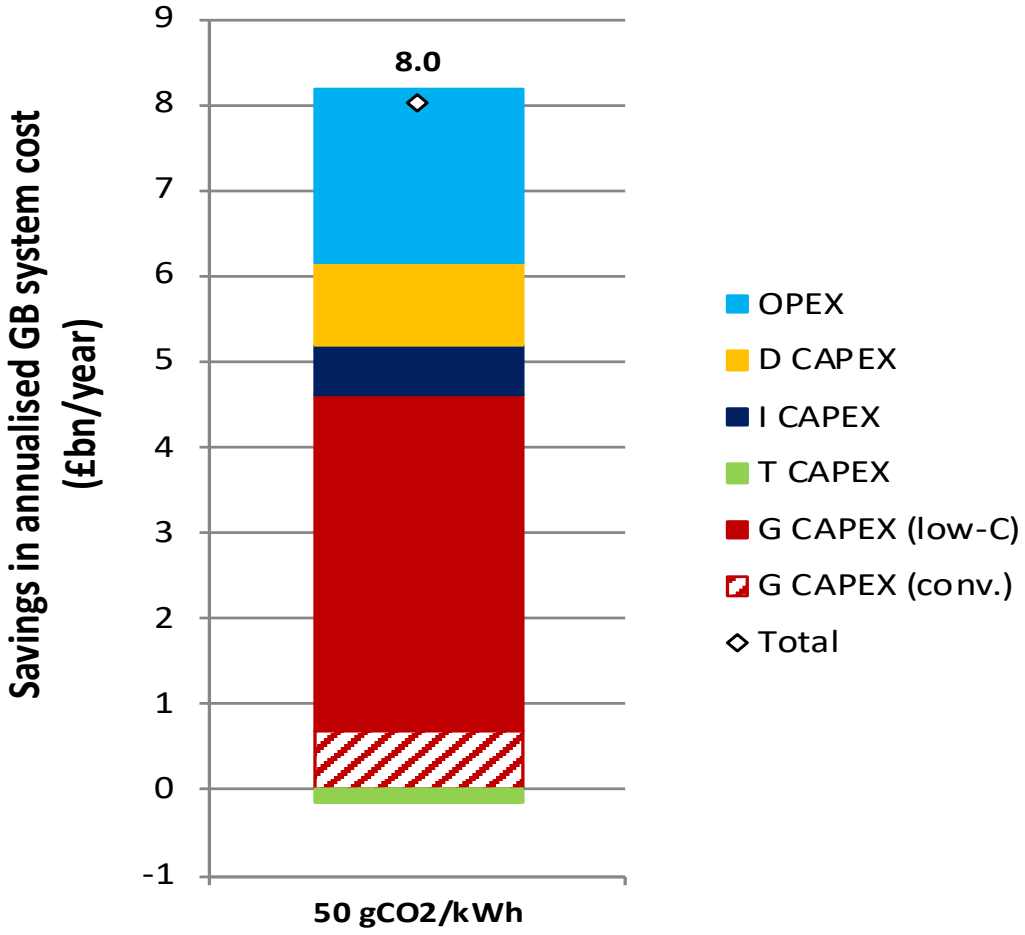

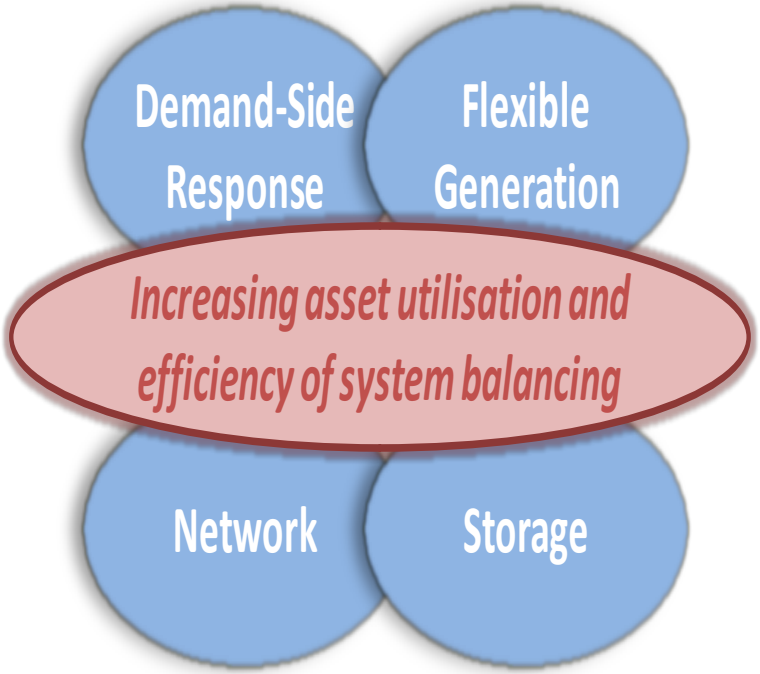

System Integration Cost: Concept and definitions

(No universally accepted definition of system integration cost)

- **Whole-System Cost (WSC)** of any generation technology represents the sum of the **Levelised Cost of Energy (LCOE)** of that technology and the corresponding **System Integration Cost (SIC)**:

$$WSC_{gen} = LCOE_{gen} + SIC_{gen}$$

- *System integration costs* or *system externalities* of LCTs: costs incurred in the system when these technologies are added to the generation mix
- SIC components include:
  - *Increased balancing cost*
  - *Network reinforcements*
  - *Increased backup capacity cost*
  - *Cost of maintaining system carbon emissions*
- **In future, SIC concept should enable a fair comparison between different low-carbon generation technologies (e.g. variable and baseload LCG)**

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Illustrative methods for calculation of *System Integration Cost*

- *Method 1 (Predefined replacement)*
  Incremental amount of LCGT capacity added, energy-equivalent nuclear capacity retired from the system, emissions maintained by adding CCS
- *Method 2 (Optimised replacement)*
  1 GW of nuclear capacity removed from the system, model optimises LCGT deployment while maintaining emissions
- *Method 3 (Difference in marginal system benefits)*
  Incremental amount of each LCGT added to the system to find marginal benefits; SIC found as difference in marginal benefits

- Whole-system model (WeSIM) optimises the counterfactual (baseline) system, and then re-optimises the system where incremental LCGT capacity is added: **SIC** = difference in total system cost divided by added LCGT output (and expressed in £/MWh)
- SIC is quantified for ***marginal*** increases in LCGT capacity, and ***relative to nuclear*** generation
- With all methods the original system ***carbon intensity is maintained constant***

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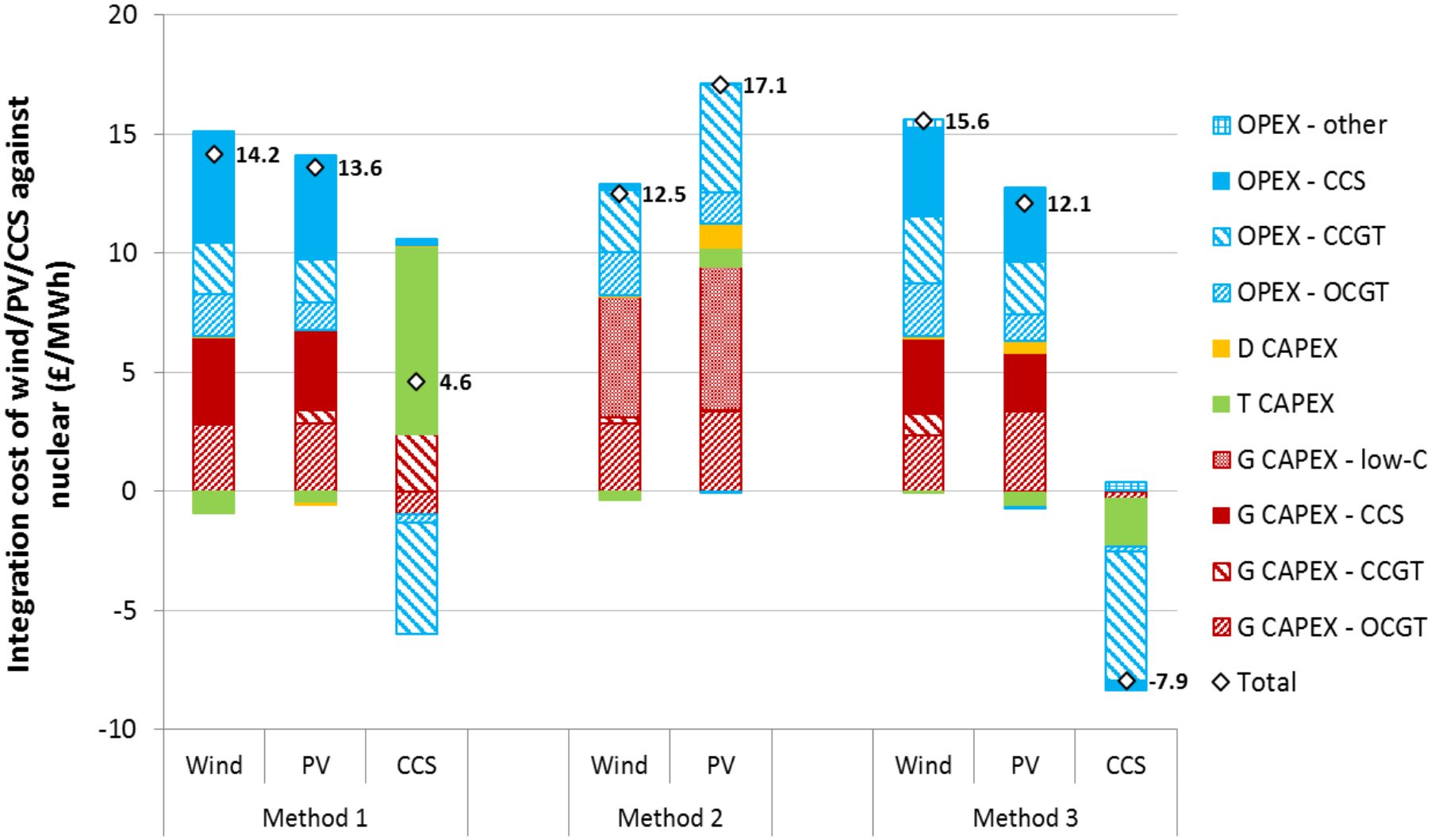
System integration cost of low-C technologies across three methods (50 g/kWh, wind-dominated)



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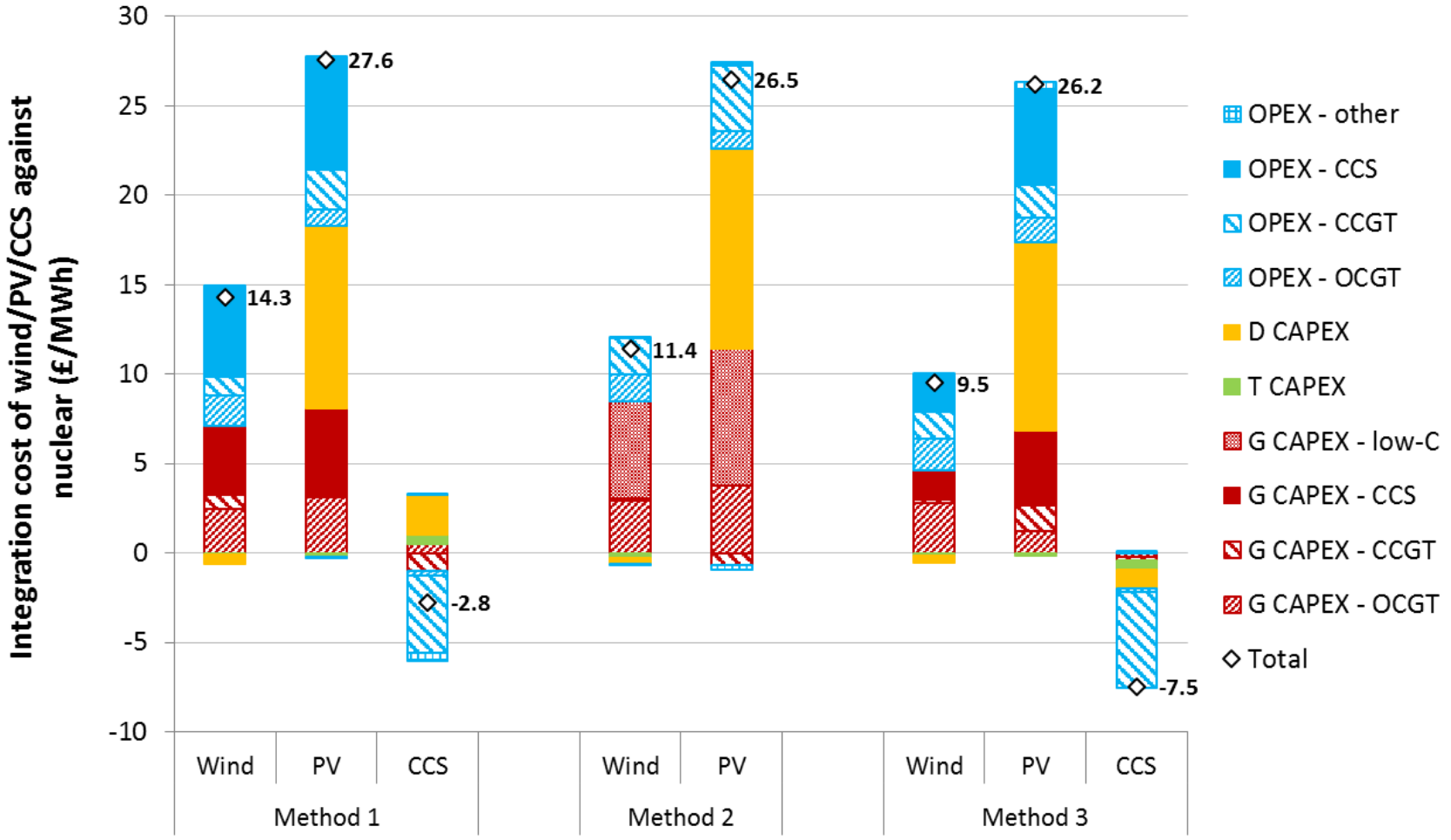
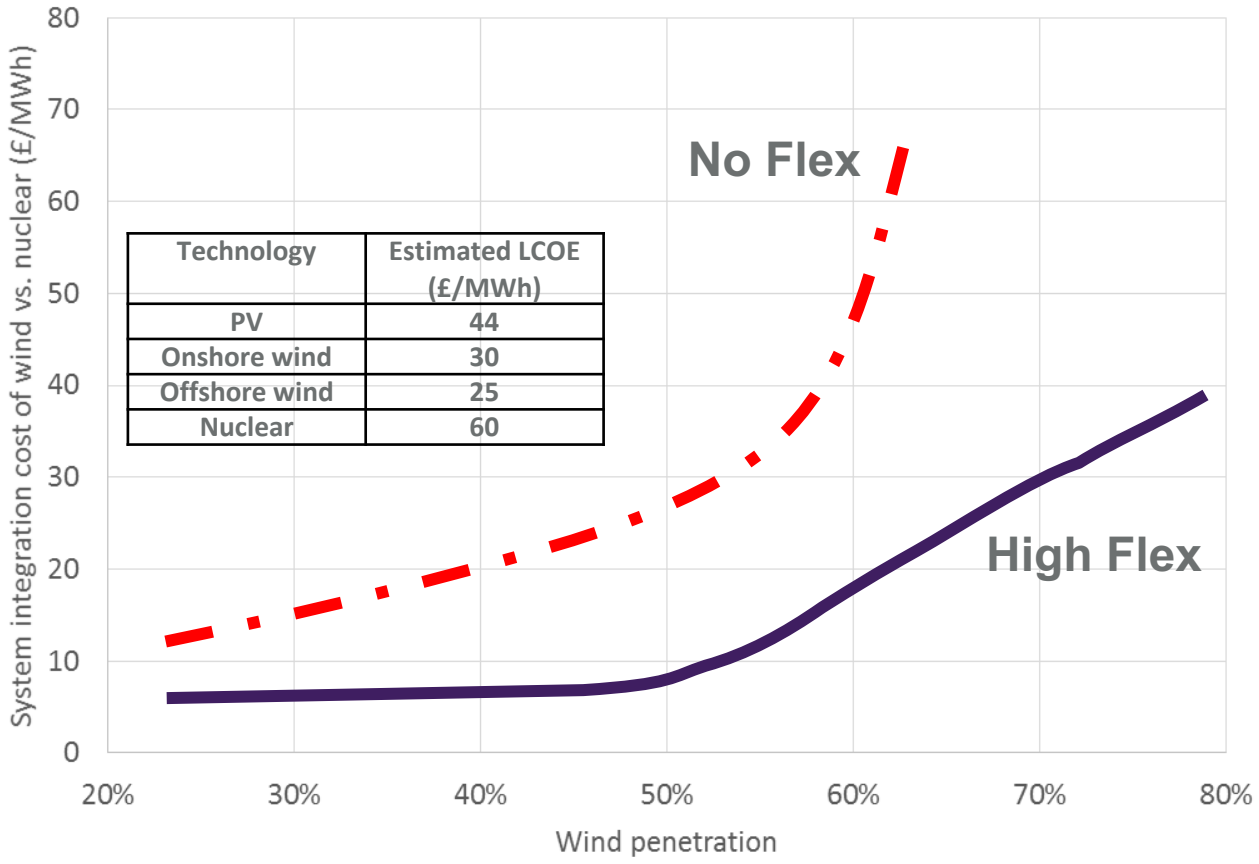
System integration cost of low-C technologies across three methods (50 g/kWh, PV-dominated)



Flexibility increases the ability of the system to integrate intermittent RES generation

$WSC_{RES} = LCOE_{RES} \pm$ System Integration Cost



Technology	Estimated LCOE (£/MWh)
PV	44
Onshore wind	30
Offshore wind	25
Nuclear	60

Whole-System Costs and competitiveness of RES driven by by system flexibility

Market design?

System Integration Cost of offshore wind (net-zero carbon)

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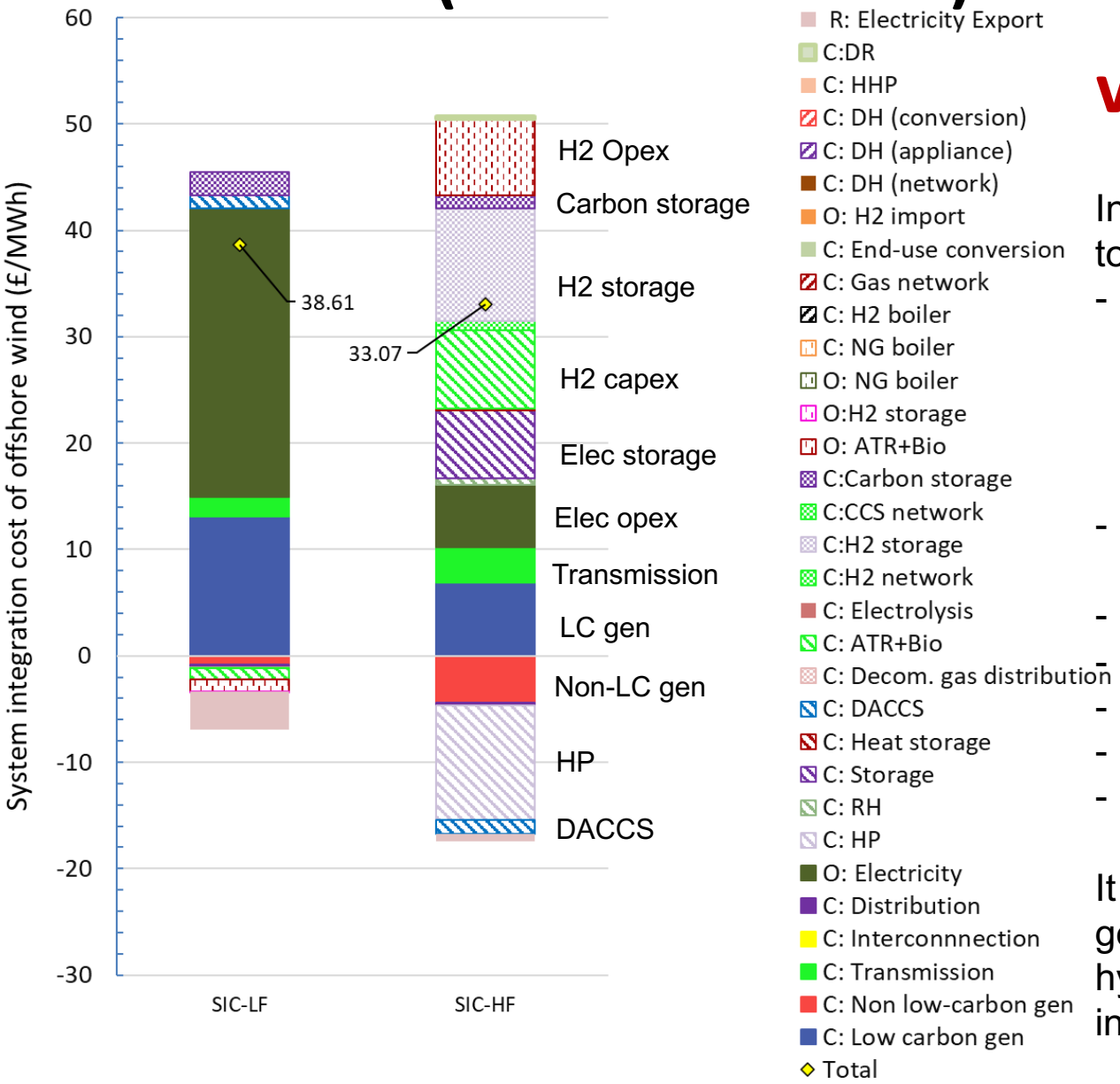

Inherent cross-vector flexibility

Increased offshore wind leads to higher:

- Cost of LC gen as it increases capacity of gas CCS (LF) or H2 CCGT (HF) due to increased balancing and need to provide capacity
- Electricity Opex (increase in CCUS)
- H2 storage
- Transmission
- H2 Capex in HF
- Carbon storage
- H2 Opex

It reduces the cost of non-LC generation and interacts with hydrogen and heating infrastructure

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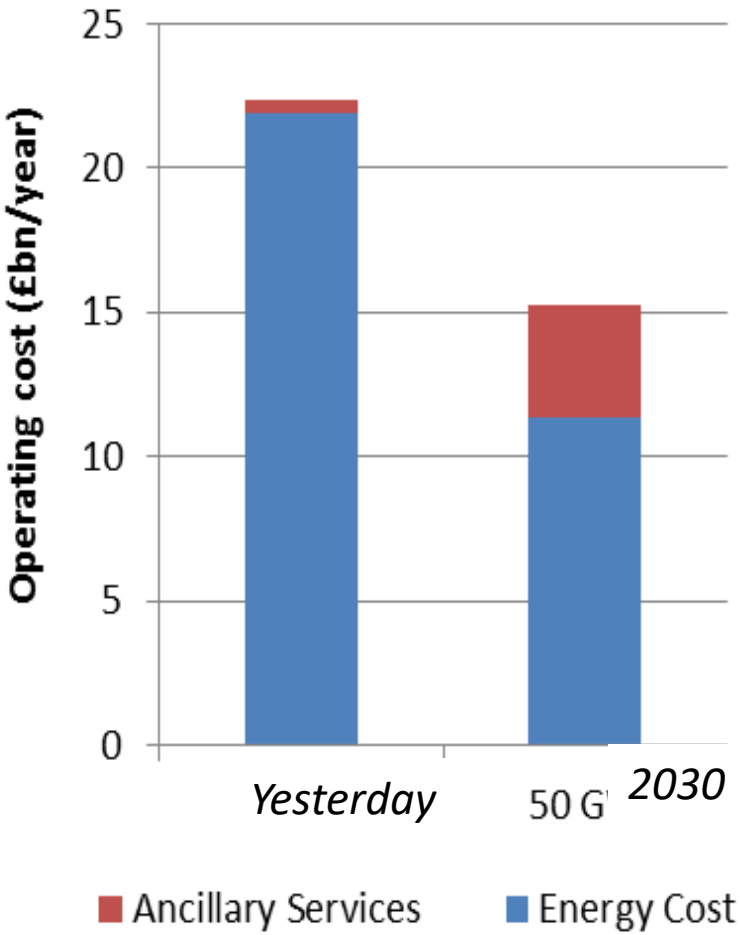
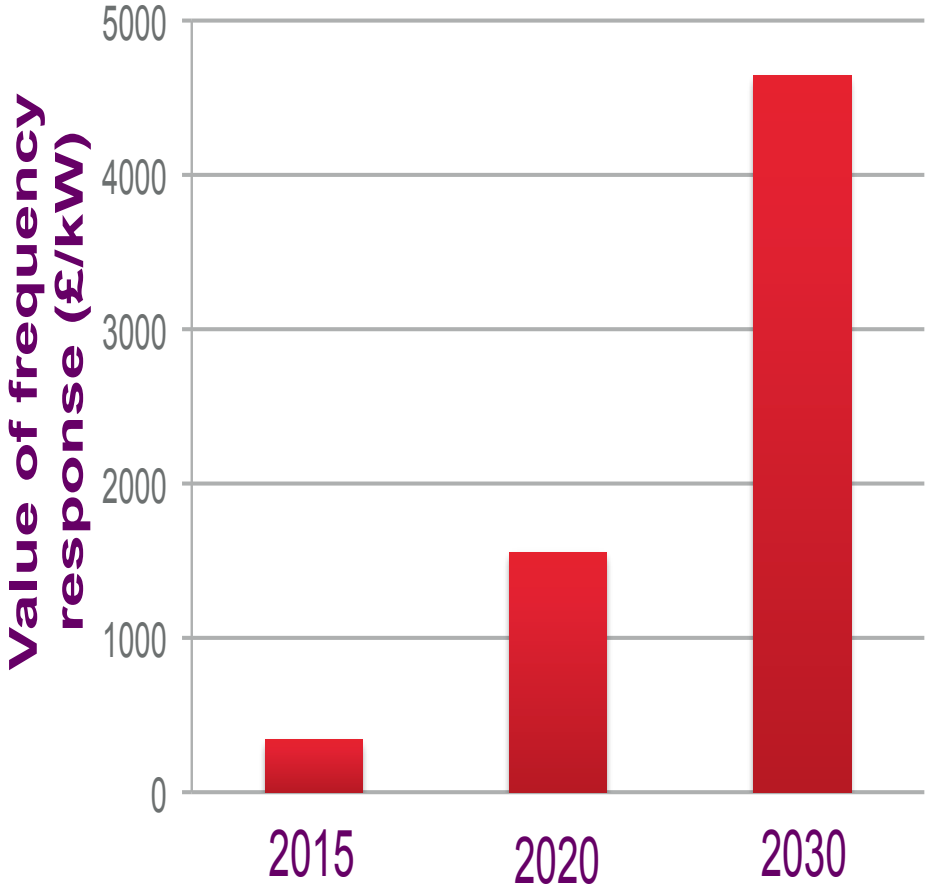
Growing need for frequency regulation related ancillary services

Share of Ancillary Services From 1.5% to 25%



Value of Frequency Response



Who should pay for this?

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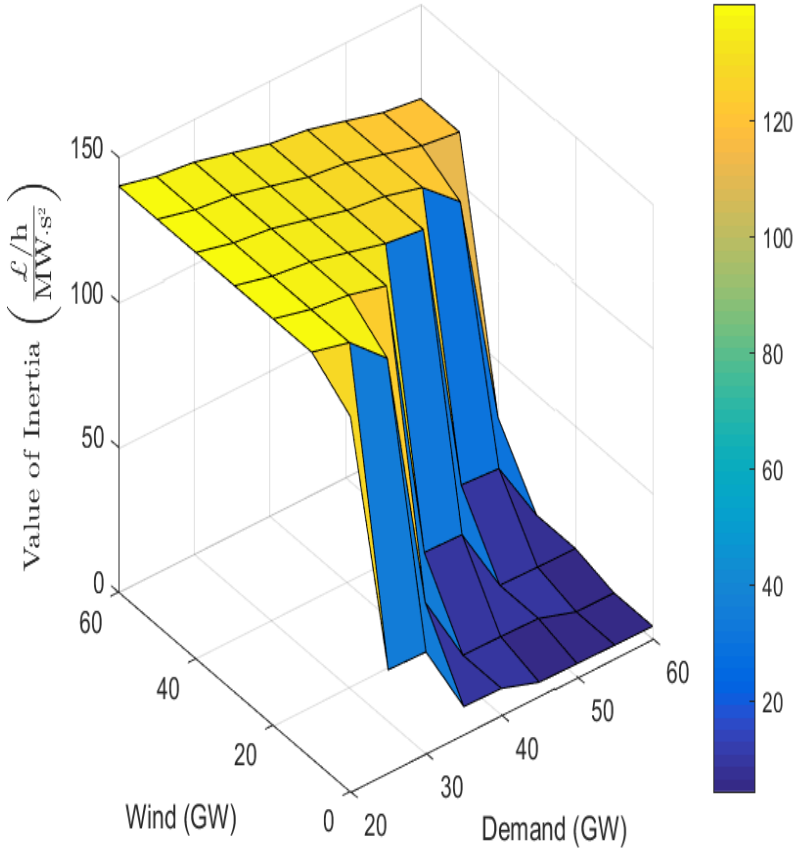
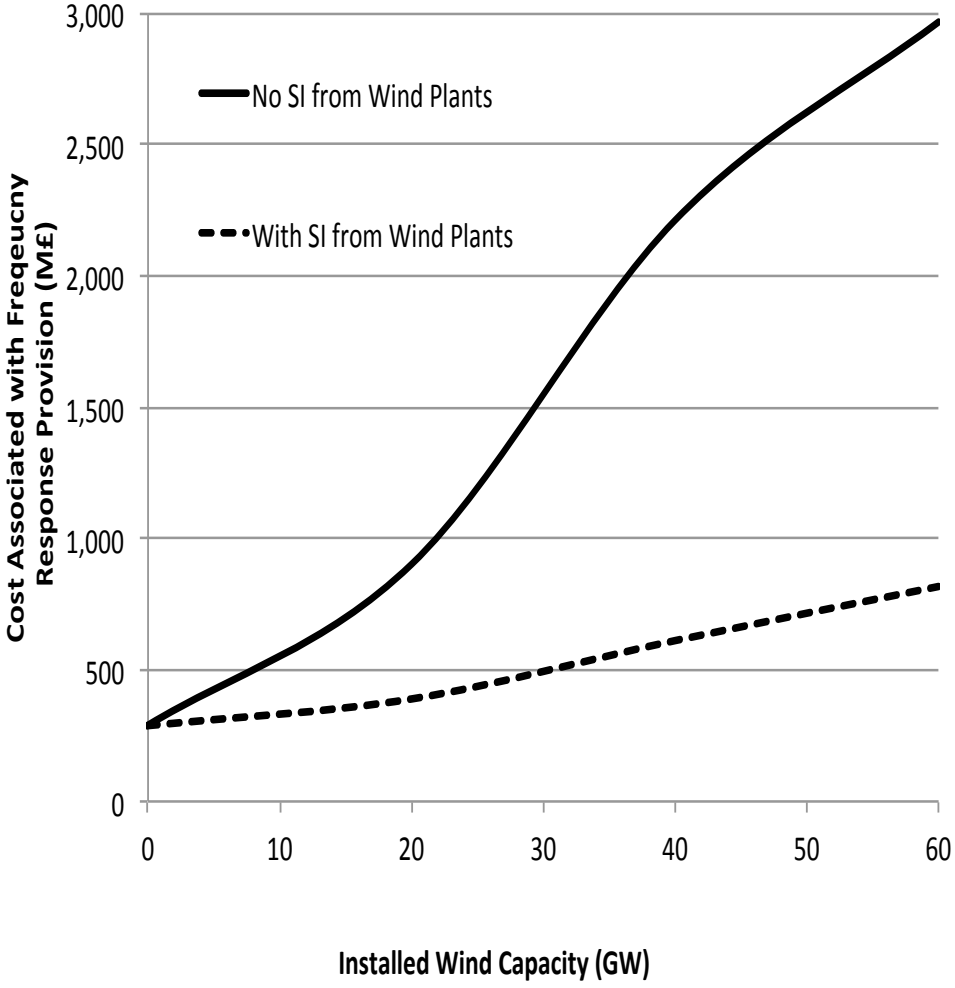
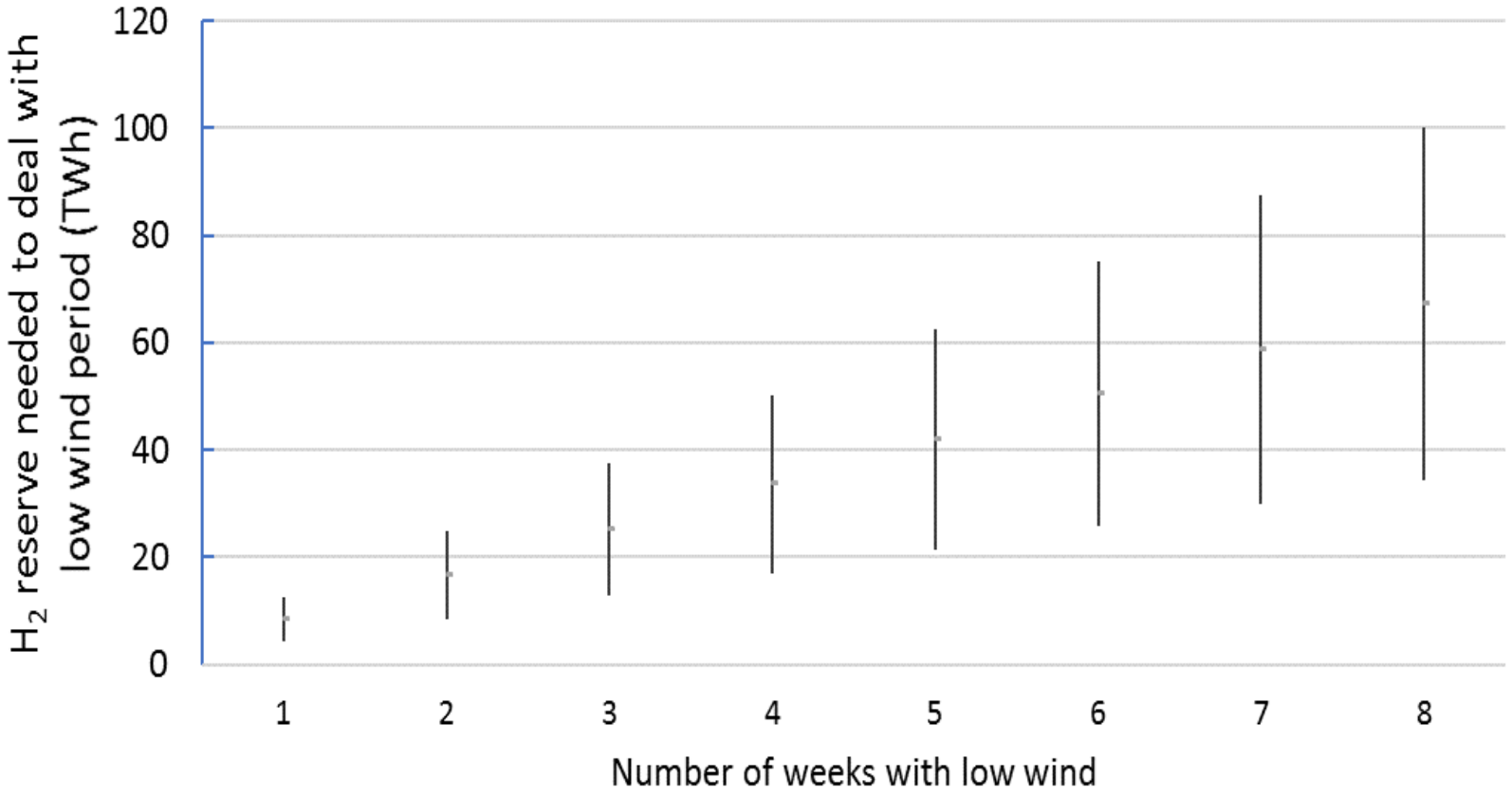
Significant value of inertia





Market for inertia – who should pay for it?

Requirement for long duration storage to deal with prolonged low RES periods



Who should pay for this?

Market (r)evolution

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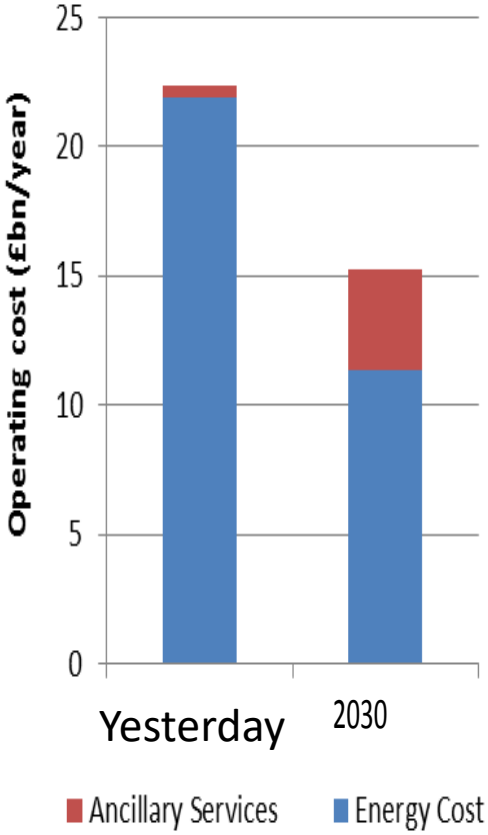

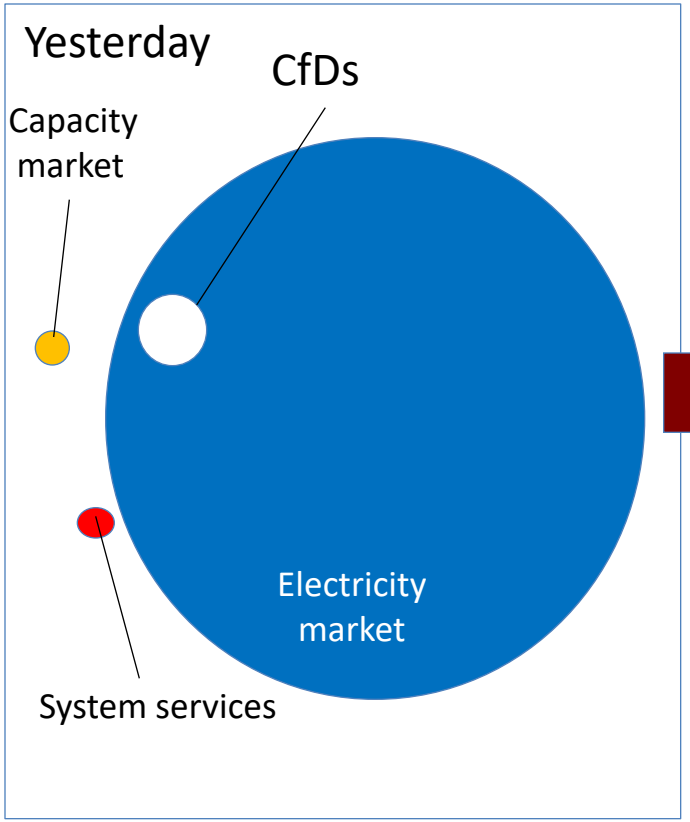

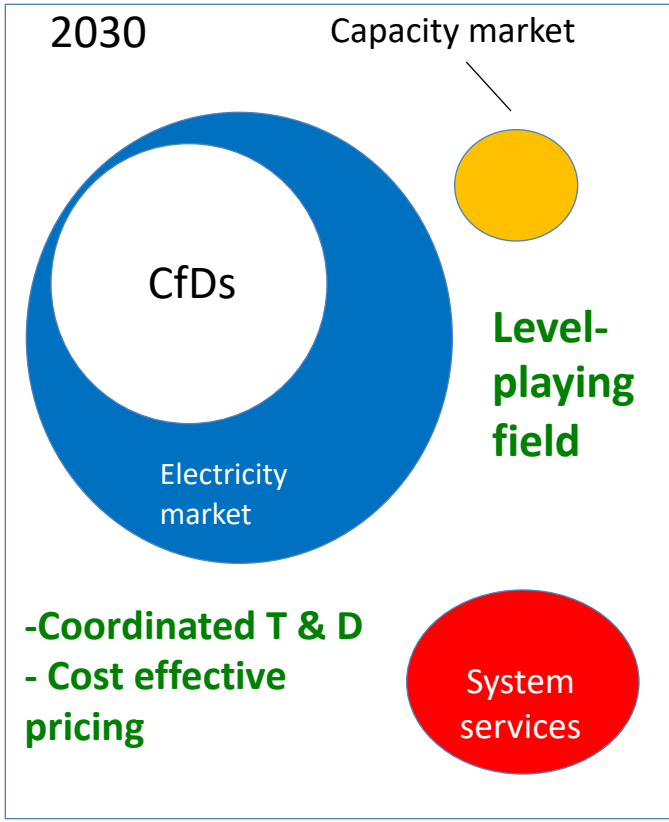

Historically, market focus has been on the energy production only

Cost effective allocation system services is needed to align objectives of investors with objectives of society

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Role of flexibility in supporting cost-efficient transition to low-carbon future

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