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Whole Systems Value of Medium-Duration Energy storage in a Net Zero GB Energy System: *Scenarios and key results*

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  - **Impact of new MDES on the annual system costs**
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  - Value of new MDES on flexible and inflexible systems
  - Benefit of providing frequency response
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  - Value of MDES with different storage capacities in the system with 50g and zero emission target
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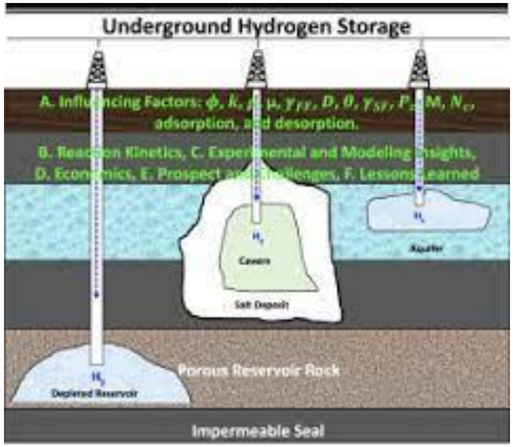
Context and objective of the studies

Context:

- Future energy system will rely on variable RES which triggers system balancing issue for short/mid-term operation and long-term seasonal energy balancing.
- Energy storage is critical to support the future system
- Medium duration (**10 – 100h**) energy storage provides a technology option that can be part of energy storage portfolio needed



Objectives:

- Identify the role and quantify the system value of medium-duration energy storage in facilitating a net-zero energy system
- Identify the value drivers, particularly focusing on the medium-term storage and flexibility

Core system background

- 2035/2050 with annual zero carbon emissions
  - Electrification of heat and transport sectors
- Demand background
  - CCC net zero scenario
  - Electricity: 478TWh/year (non-heat)
  - Heat: 633 TWh/year
- Medium flexibility with demand response and energy storage
  - DR, I&C, smart EV, Smart Appliances
- Heat and transport are decarbonised via electrification
- LCOE of low-carbon generation
  - Wind: £50/MWh
  - PV:£40/MWh
  - Nuclear: £70/MWh
  - CCS: £90/MWh
- Integrated hydrogen system
  - Supply mix : a combination of advanced methane reformers and electrolysers
  - H2 storage: underground and medium pressure overground
  - 93 TWh of hydrogen from BECCS; this is used for H2 fuelled generation
- GB is energy neutral (zero net import/export annually)

Modelling approach

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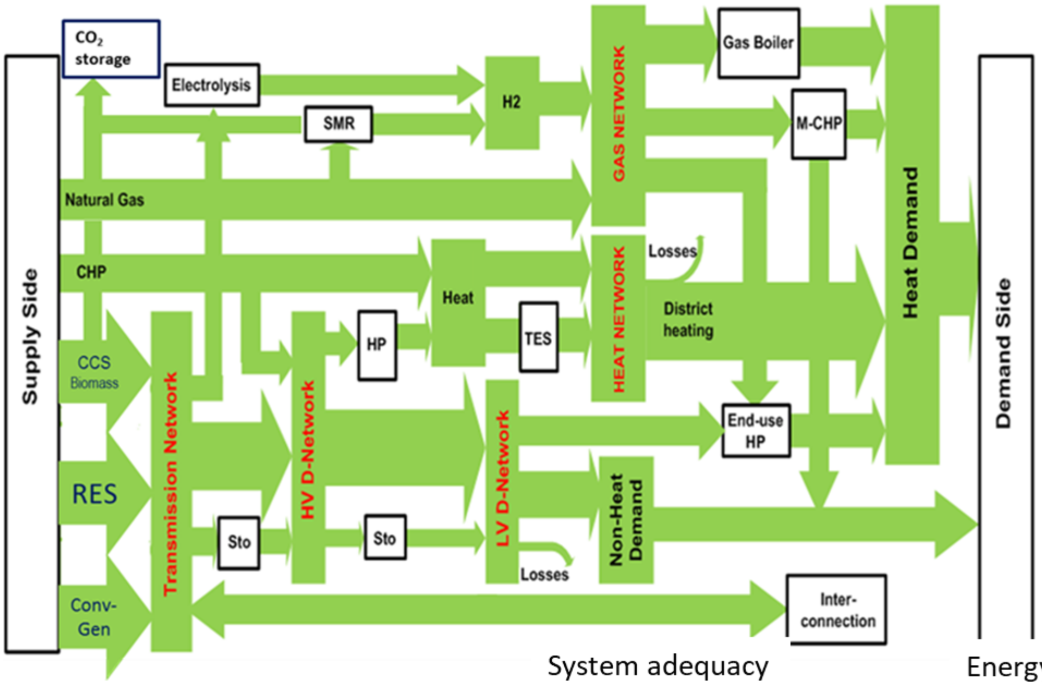
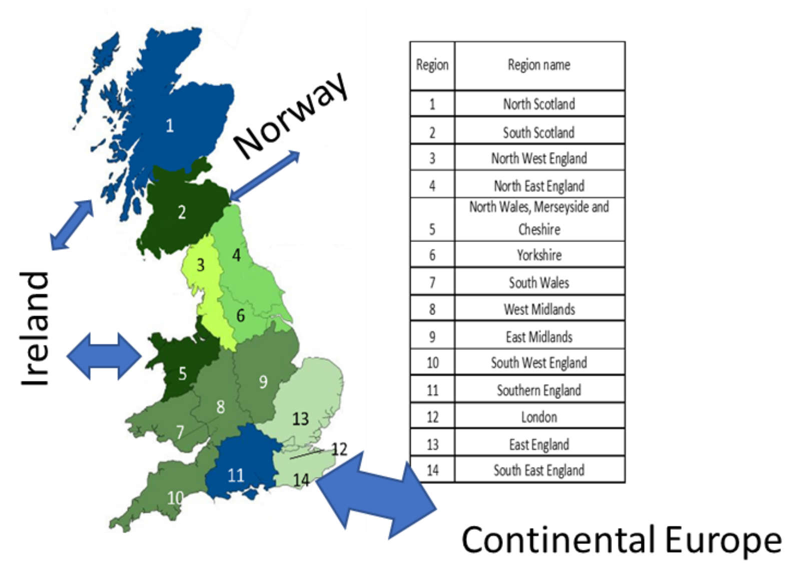
Modelling of technologies



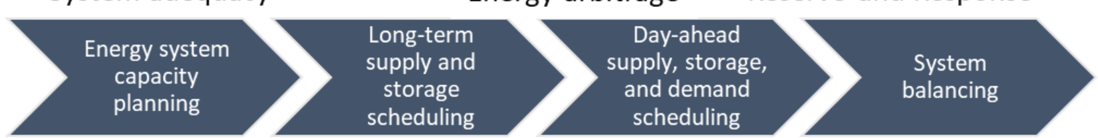
Spatial resolution:

Local & National ***level***



Region	Region name
1	North Scotland
2	South Scotland
3	North West England
4	North East England
5	North Wales, Merseyside and Cheshire
6	Yorkshire
7	South Wales
8	West Midlands
9	East Midlands
10	South West England
11	Southern England
12	London
13	East England
14	South East England

System adequacy | Energy arbitrage | Reserve and Response



Years before delivery | Months to days before delivery | One day to one hour before delivery | Actual delivery: physical supply and consumption (second timescale)

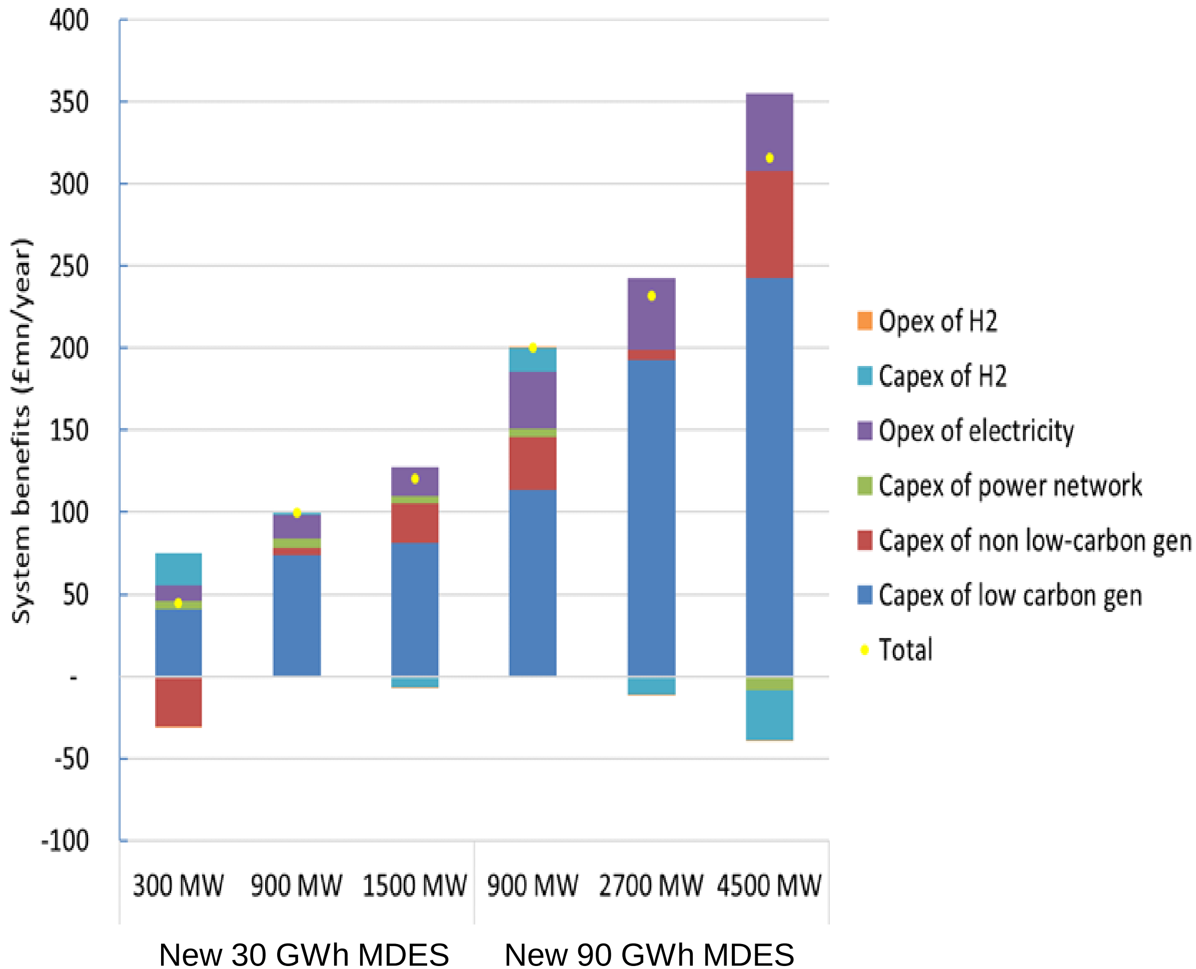
Temporal resolution

IWES – *Integrated, Whole-Energy System model*

Benefits of Medium-Duration Energy Storage

- New medium duration energy storage (MDES) would **enable net zero to be met at lower cost** (system savings of between £500m and £3.5bn in 2035/2050):
  - Reduces the need for higher-cost firm low-carbon generation technologies, such as nuclear and thermal plants with CCS
  - Cost-effective integration of variable renewables by reducing curtailment
  - Reduces emissions of system balancing by displacing some conventional (fossil-fuel-based) mid-merit and peaking plant
- **Manages network congestion** more efficiently and reduces the need for transmission reinforcement
- Improves the efficiency of system operation by reducing costs associated with the **provision of frequency response and balancing services**
- MDES competes with other forms of flexibility, including demand side, interconnection and hydrogen.
  - However, these flexibility technologies play a **complementary role** with MDES, providing significant benefits in all scenarios.

System benefits of MDES

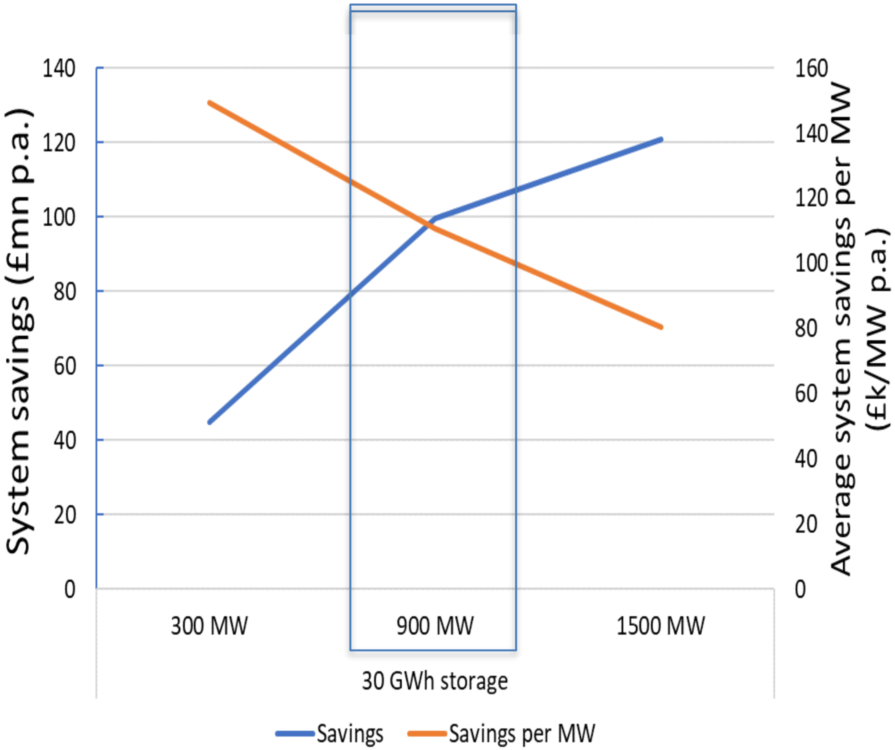


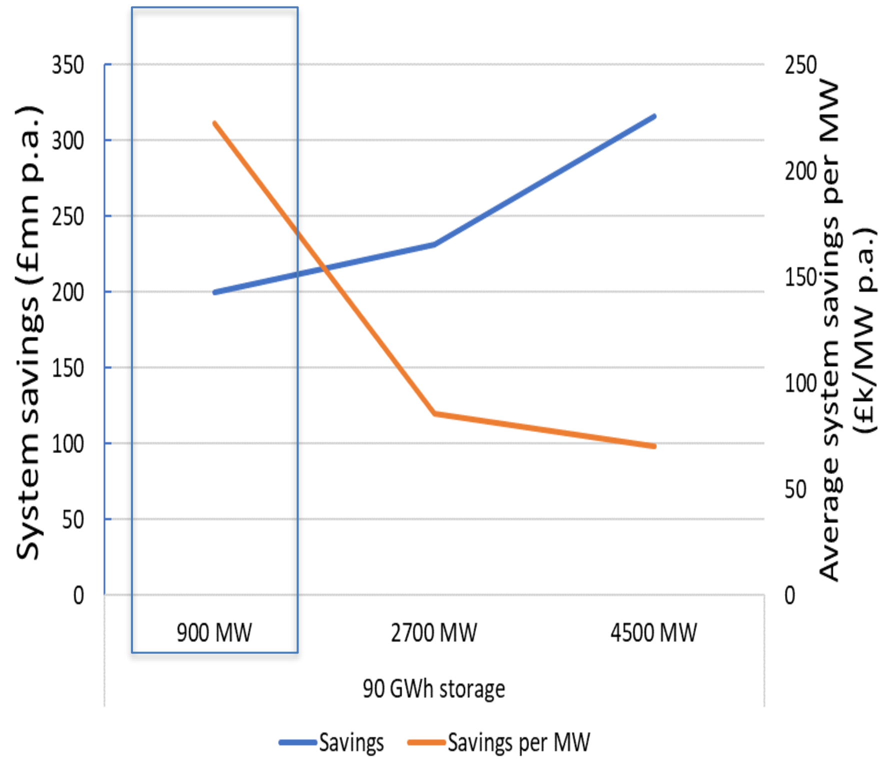
* Gross benefits (the cost of new MDES excluded)

- MDES – between 20 and 100h
- Total cost savings: £500m - £3.5bn/year
- Value is system specific
  - 30 – 90 GWh of energy storage
  - 300 MW – 4500 MW installed capacity

- 75% of the savings are from the avoided capital cost in low-carbon electricity generation

Gross value of MDES

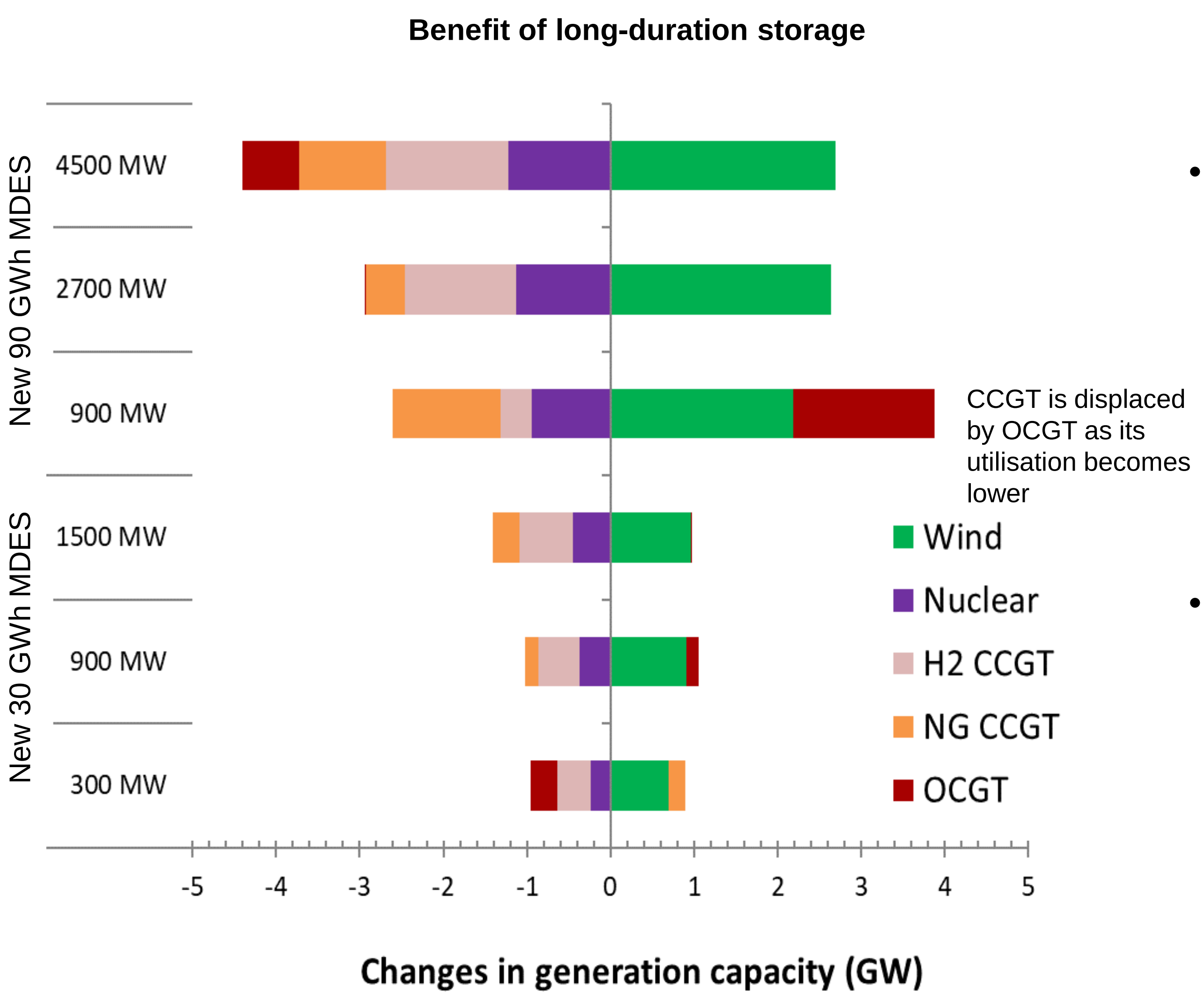




- Higher value for longer-duration energy storage
- The incremental benefit of increasing power capacity (savings per MW) decreases

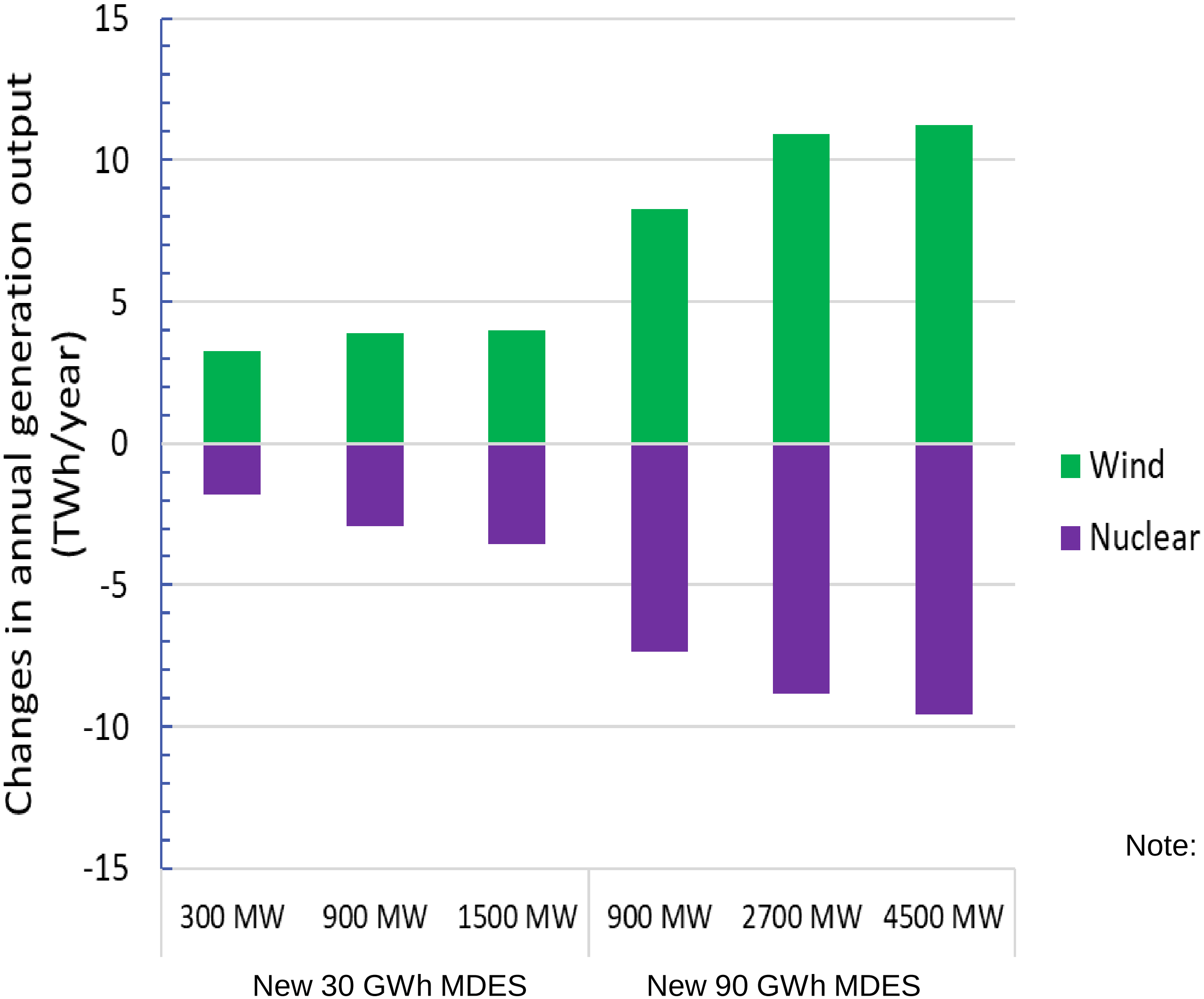
Case 900MW power size, duration 33h and 100h

Impact on power generation capacity



- MDES increases the capacity of wind that can be integrated to the system.
- The volume of nuclear that can be displaced per MW installed MDES depends on the energy storage capacity
  - 100h storage: 0.75 to 1 MW/MW MDES
  - 20h storage: ~0.3 MW/MW MDES
- MDES brings more Some CCGT capacity can also be displaced (or substituted by OCGT running with green gas) as its capacity factor decreases)

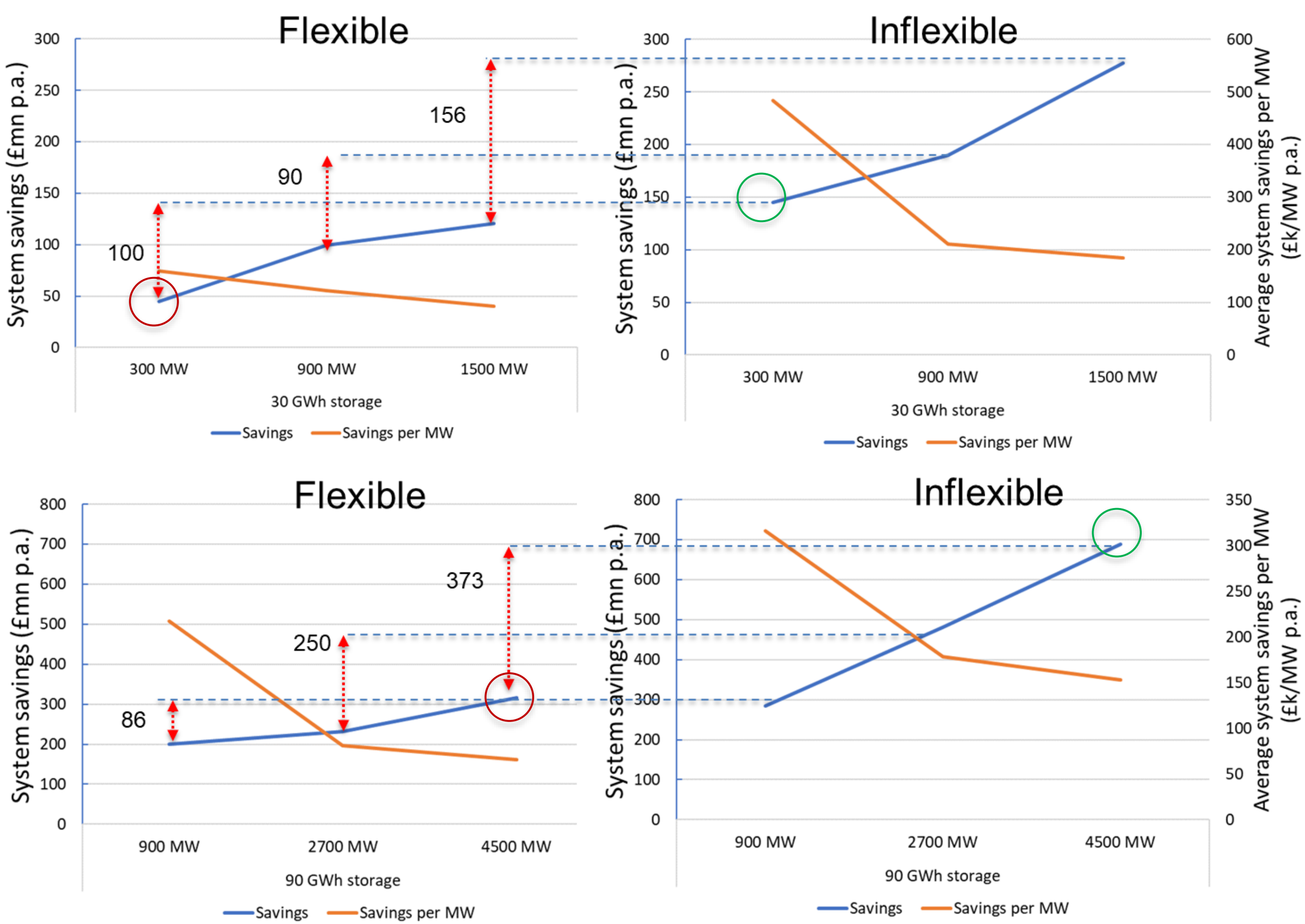
Impact on electricity production from nuclear and wind



- MDES reduces the integration cost of wind
- Higher volume of wind can be integrated (up to 11 TWh/year)*
- Less nuclear power needed

Note: * within the range of studies

Value in flexible and inflexible energy systems



- Flexible: with demand response from I&C, EVs, SAs, energy storage
- Inflexible: no demand response, no new energy storage except the new MDES

The value of MDES is between £44m and £316m per year in 2050 even in a highly flexible system with competing technologies. In an inflexible system the benefit of MDES increases to £150m - £700m per year.

MDES benefits (flexible systems) < MDES benefits (inflexible systems)

MDES provides more flexibility, which improves system efficiency

Role and value of Variable Speed ES (e.g. PHES) in the context of frequency regulation - difference between short and medium duration storage

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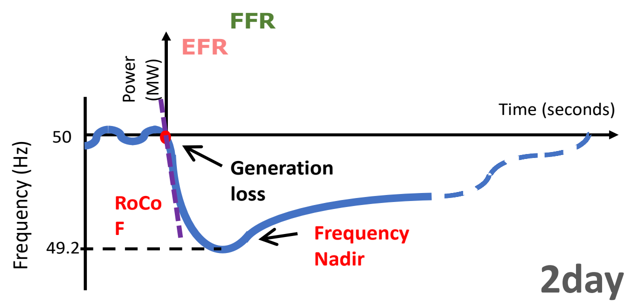
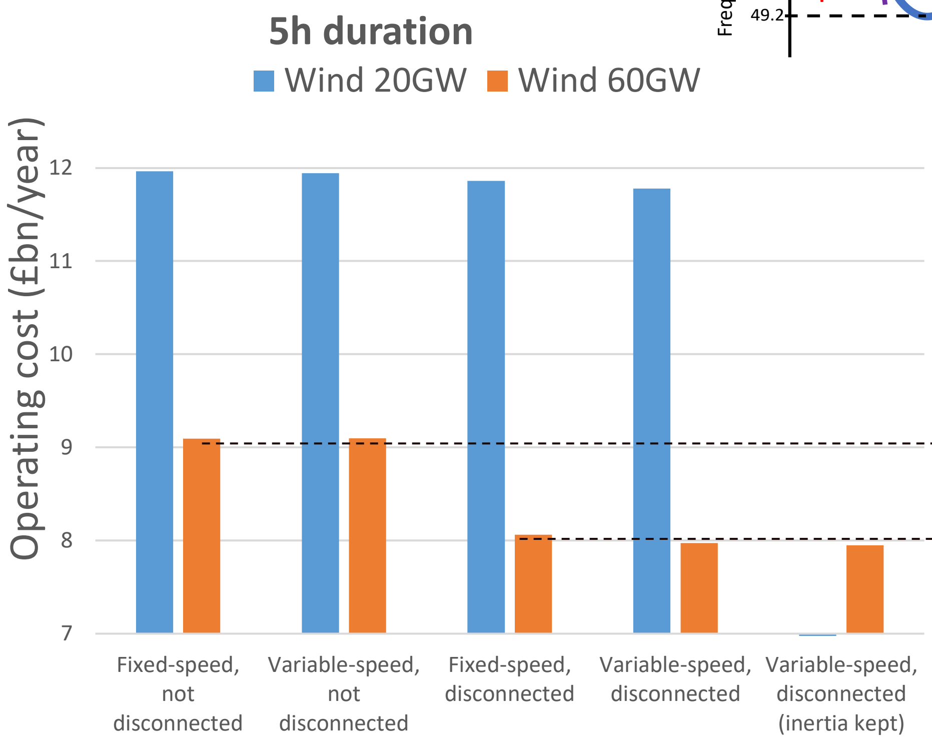
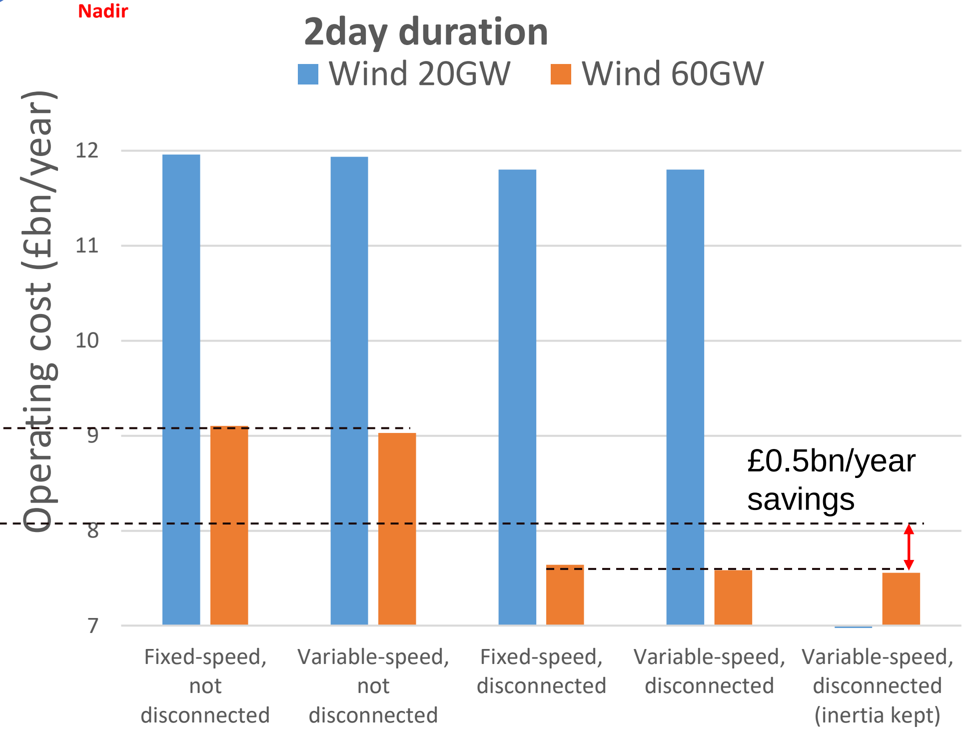
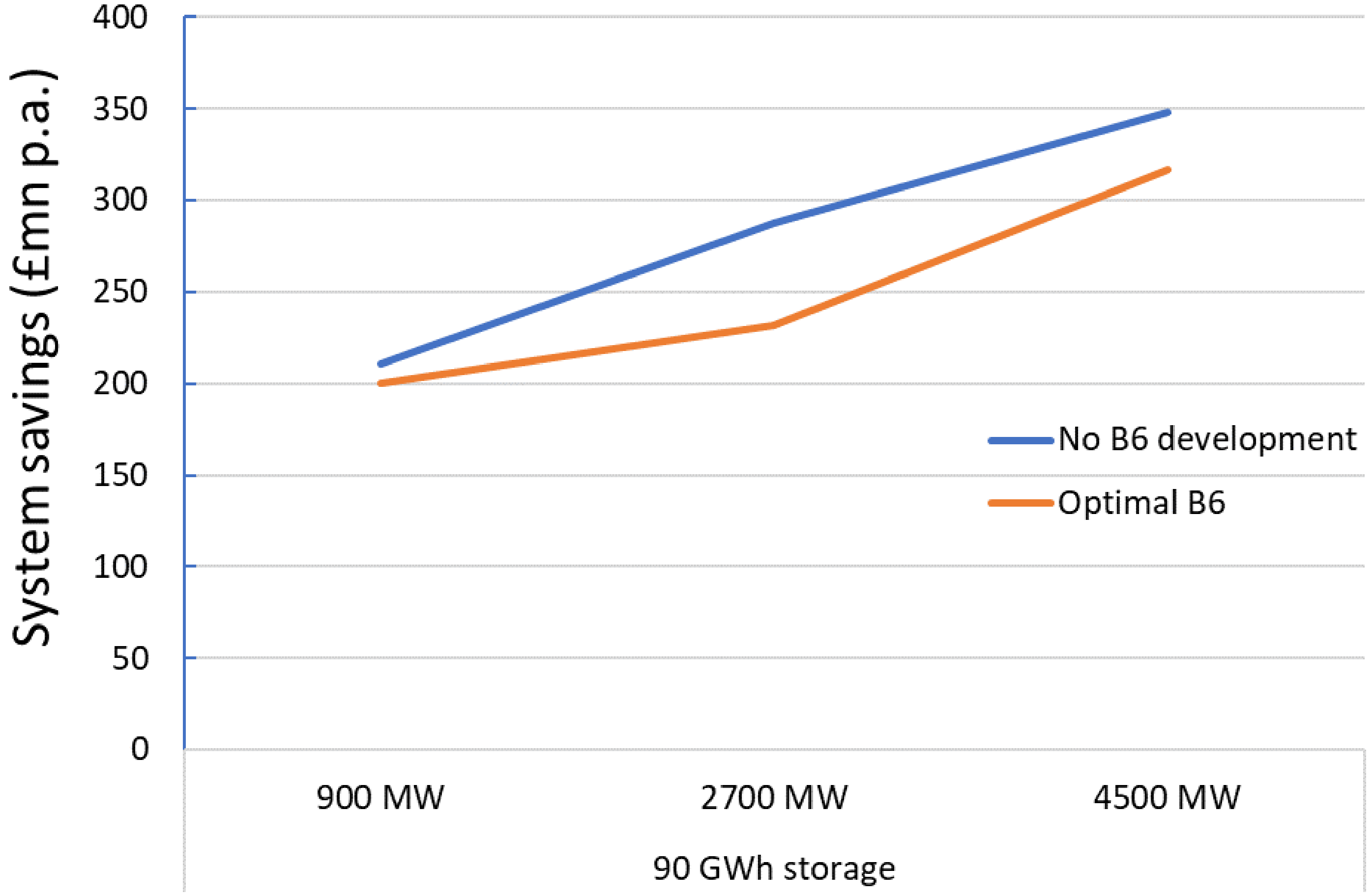






Assuming that ES units in charging mode could **provide fast frequency response** by disconnecting after an outage, and potentially **provide inertia**

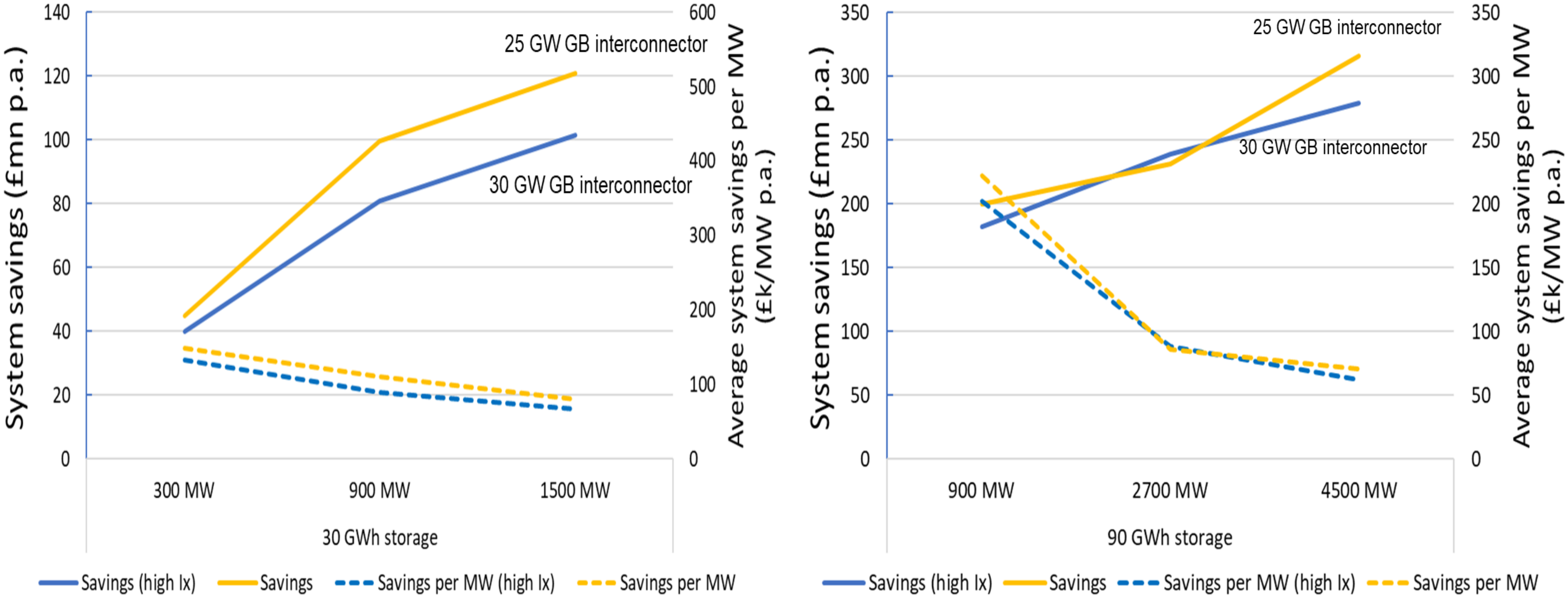
Impact of constraint on the Scotland-England boundary capacity



(6 GW)

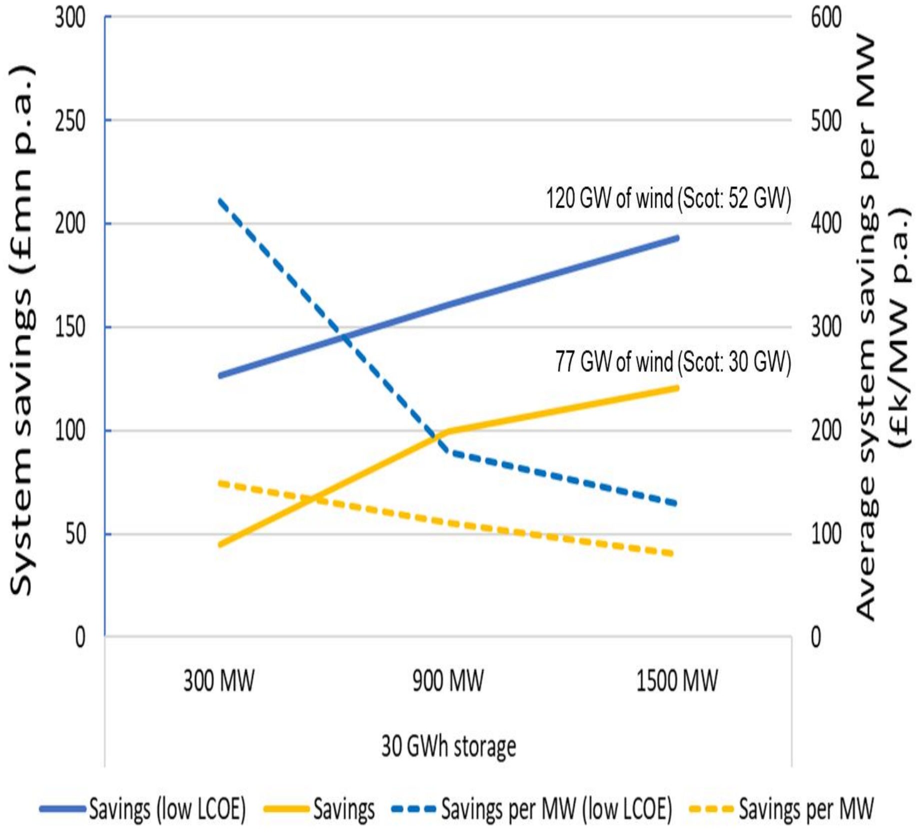
Value of MDES is higher if transmission capacity is suboptimal

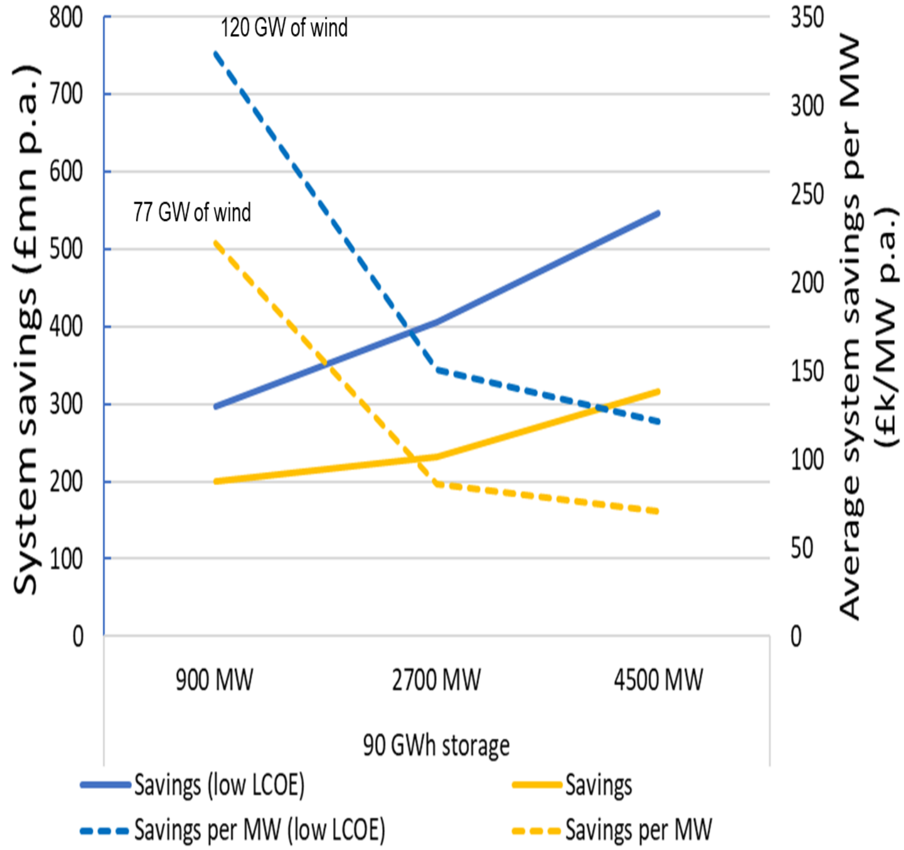
Impact of high GB interconnection with Europe



MDES competes with interconnection; therefore, increased GB interconnection tends to reduce the benefits of new MDES (and vice versa).

Impact of lower wind LCOE





Increased wind (e.g. driven by lower wind LCOE) will intensify the benefits of MDES especially with long duration capacity

Value of Medium Duration Energy Storage in different scenarios

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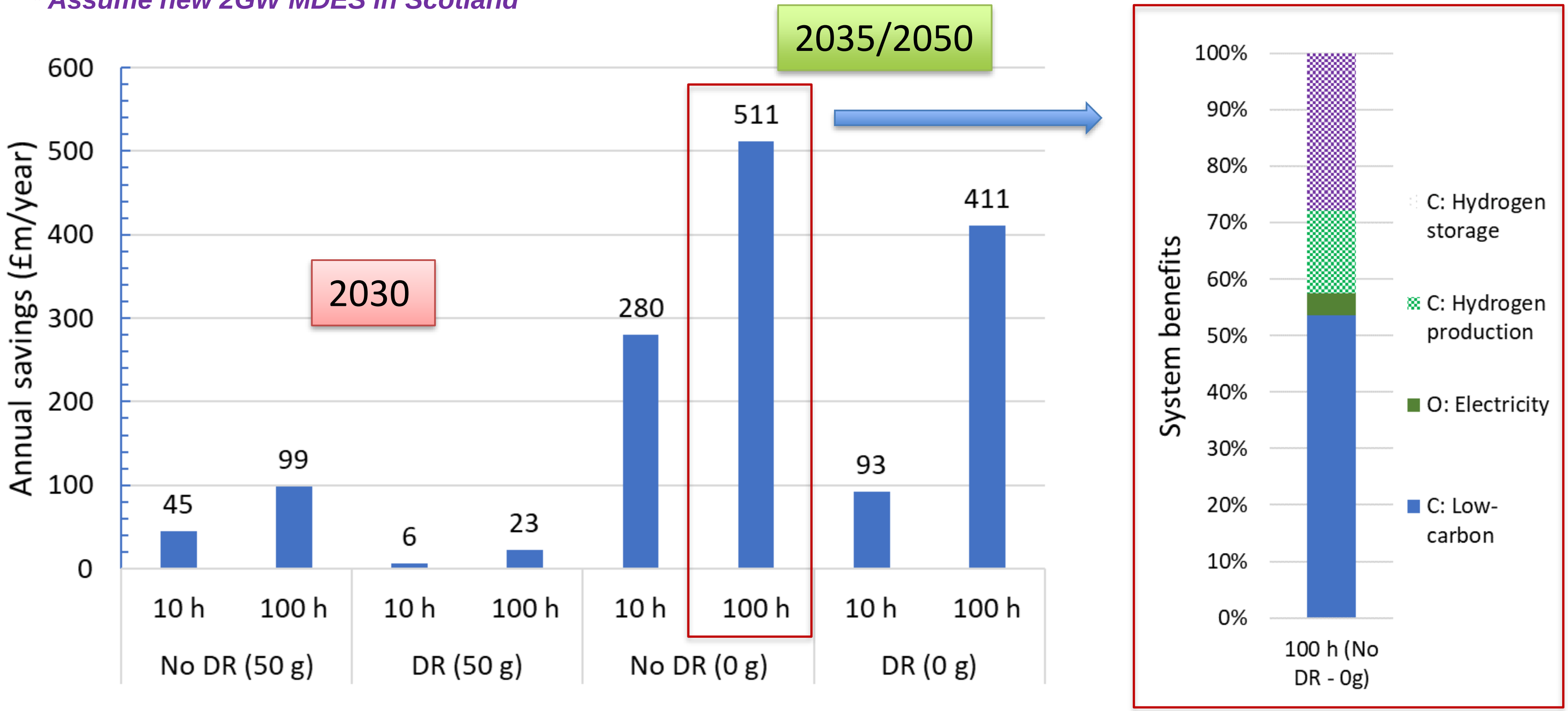
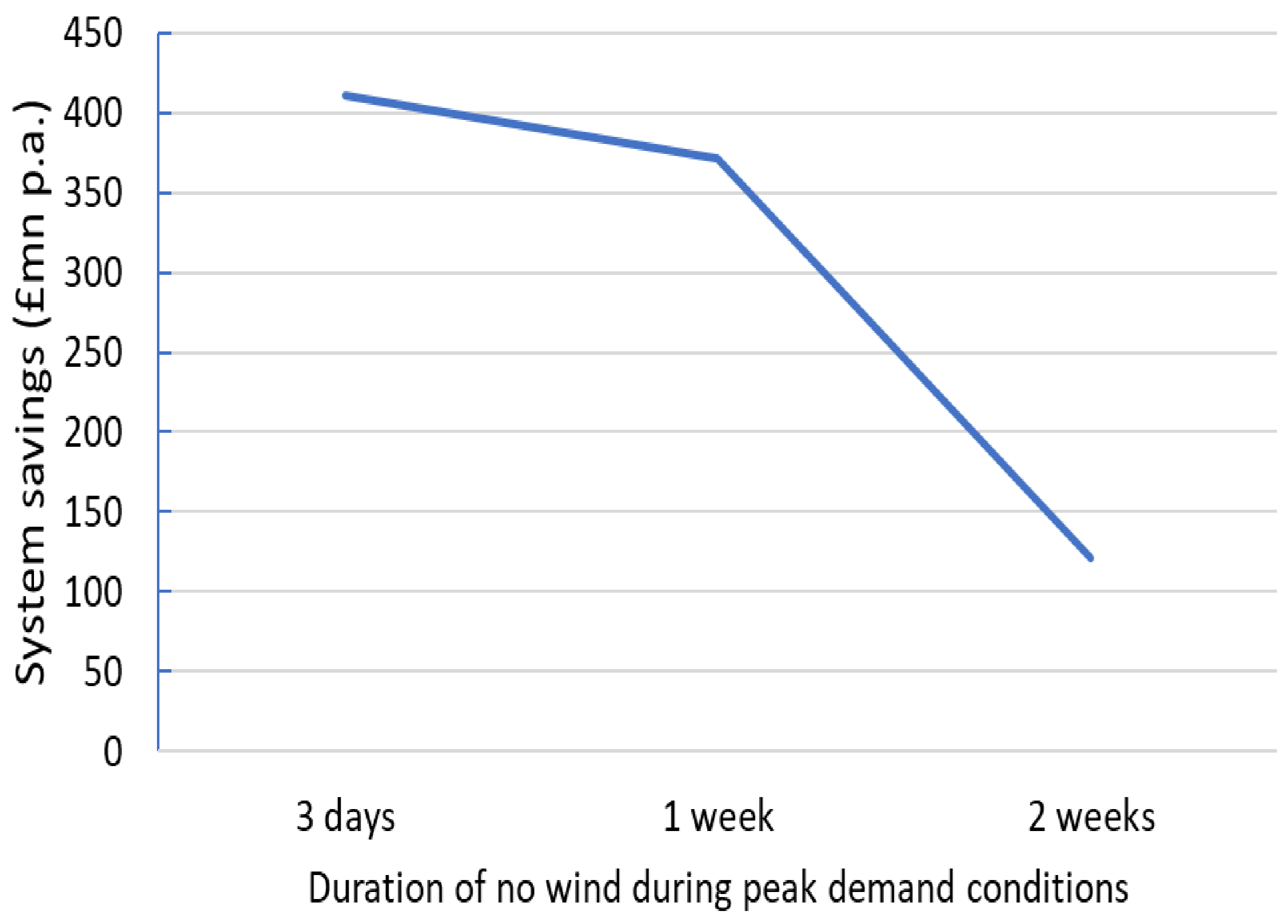
**** Assume new 2GW MDES in Scotland***



- Value of longer duration (100h) ES is higher than shorter duration (10h) storage
- Most of benefits are in the savings in low-carbon generation (power and hydrogen), Opex, and reduces other form of flexibility or energy storage
- Drivers:
  - Net-zero emission system
  - Low flexible electricity system

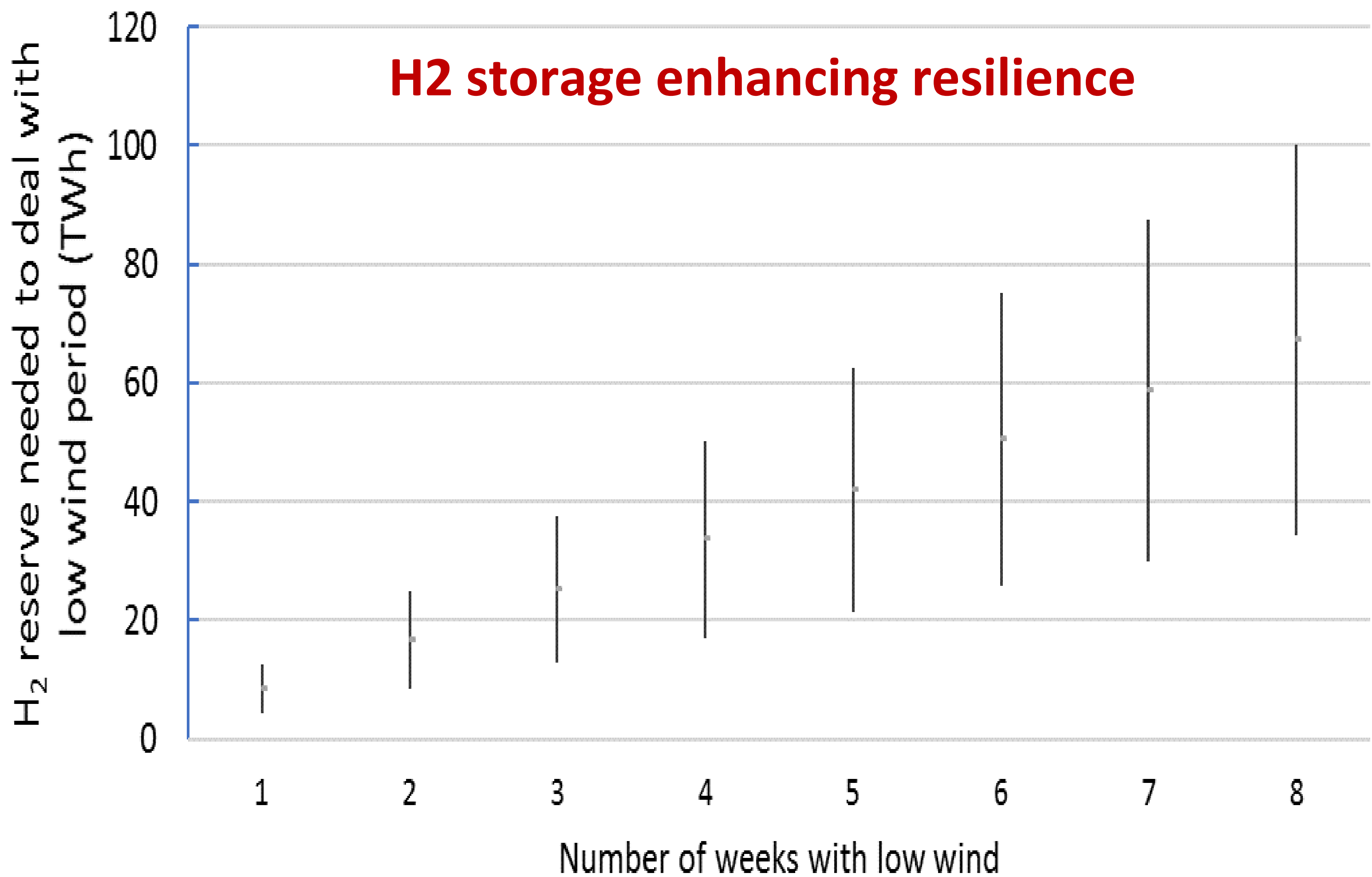
Impact of prolong low wind output during peak demand



- The need for medium duration storage depends on how long the service is needed consecutively, e.g. during prolonged low-wind output in winter
- Extreme scenario (e.g. more than 1-week low-wind output) reduces the benefits of 100h MDES

Scenario: 2GW, 100h new MDES in Scotland

Additional H2 storage to deal with prolonged low/no wind periods



Market frameworks to capture the system benefits of MDES

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MDES electricity system benefits

- Provide capacity
- Facilitate the integration of low-cost low-carbon technologies
- Improve network congestion management
- Energy arbitrage
- Frequency response and reserve services

Electricity market frameworks

- Capacity market
- ?
- Network charges
- Balancing Mechanism
- GB wholesale market
- Ancillary service market

The largest benefit of MDES (75%) is reducing the cost of low-carbon technologies primarily driven by the need for reducing carbon emissions.

Policy and market challenges should be addressed

Summary of key findings /1

- Role of MDES
  - Improve integration of variable RES
  - Reduce the need for high-cost firm low-carbon energy sources such as nuclear or CCS
  - Provide ancillary services and capacity (displacing capacity of mid-merit and peaking plant)
  - Support network congestion management
  - Allow arbitrage that can improve the utilisation of base load or RES plant
- Gross benefits of £440m - £3.16bn
- Value of MDES varies in a large range depending on system conditions (system specific). High value is driven by
  - High RES penetration, e.g. driven by low wind LCOE (max value up to £5.5bn)
  - Low carbon target – it drives the need for firm low-carbon energy sources
  - Low system flexibility e.g. limited availability of demand response technology (value up to £7bn)
  - MDES is able to provide ancillary services, e.g. frequency response
  - Constrained network between Scotland and England or limited interconnection capacity

Summary of key findings /2

- MDES competes with other flexibility sources
  - Who comes first gets a higher value (speed of deployment is essential)
  - But even with a substantial demand response, the value of MDES is still substantial
- MDES providing frequency response
  - For a system with high wind (60 GW), the value of MDES is significant (i.e., an additional £0.5bn/year)
- Suitable policy and market frameworks for MDES are still needed to be developed.