Imperial College London

Medium-Duration Energy Storage in the Net-Zero UK

Role and Value of Energy Storage in Future UK Low Carbon Energy System

Goran Strbac, Danny Pudjianto, Marko Aunedi, Xi Zhang

Imperial College London

March 2020

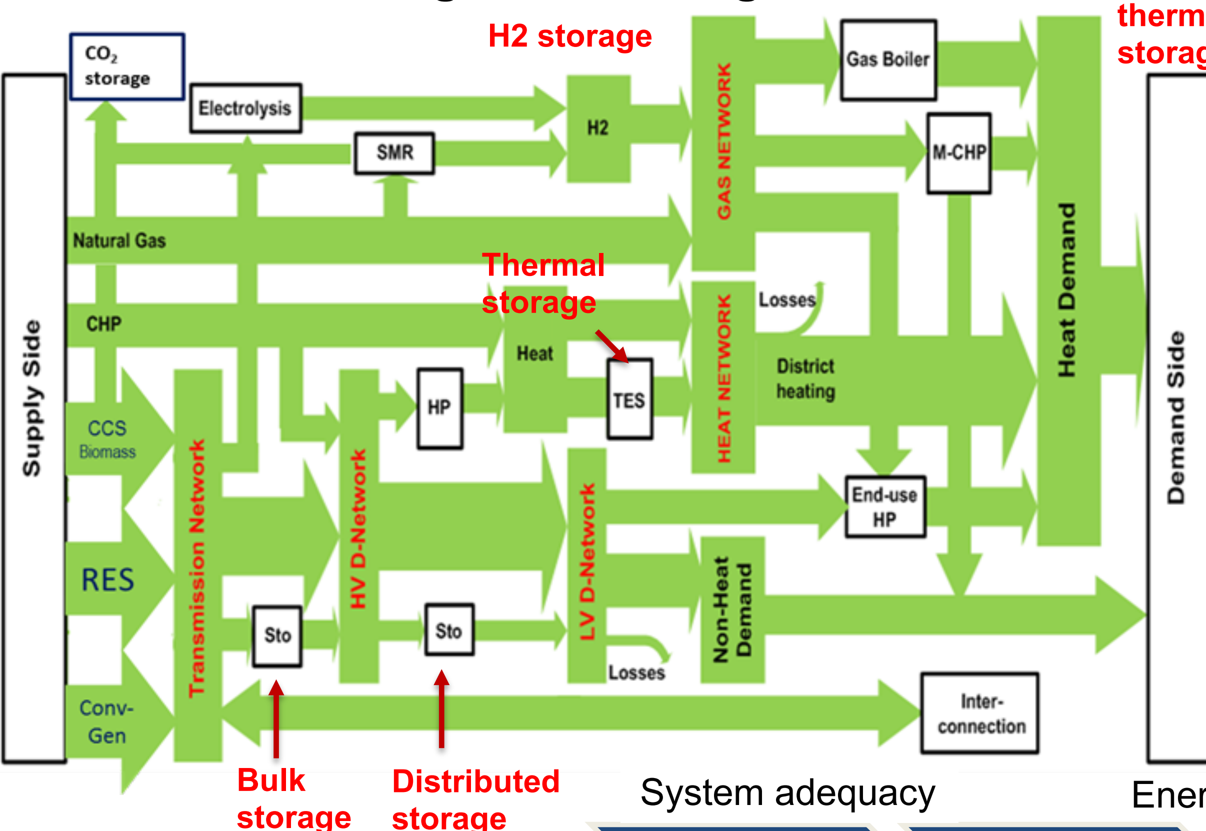
Role and Value of Energy Storage: Research Questions

Imperial College London

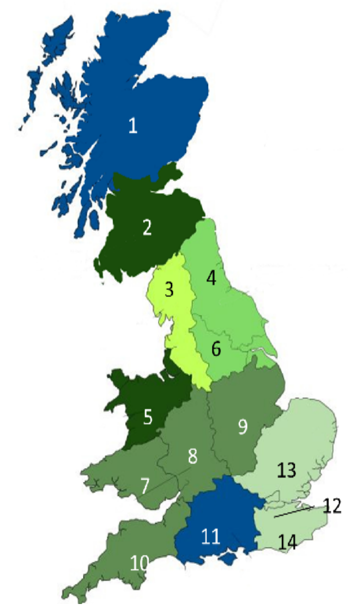
- What are the system implications of energy storage?
  - Facilitating cost effective decarbonisation
  - Providing flexibility in system operation in different timeframes
- How to quantify the whole-system benefits of energy storage?
- How to identify the optimal portfolio of energy storage technologies and the potential market volume?
- What are the key drivers for energy storage?
- What is the role and value of medium/longer duration energy storage?
- How energy storage competes with other technologies?

Modelling approach

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

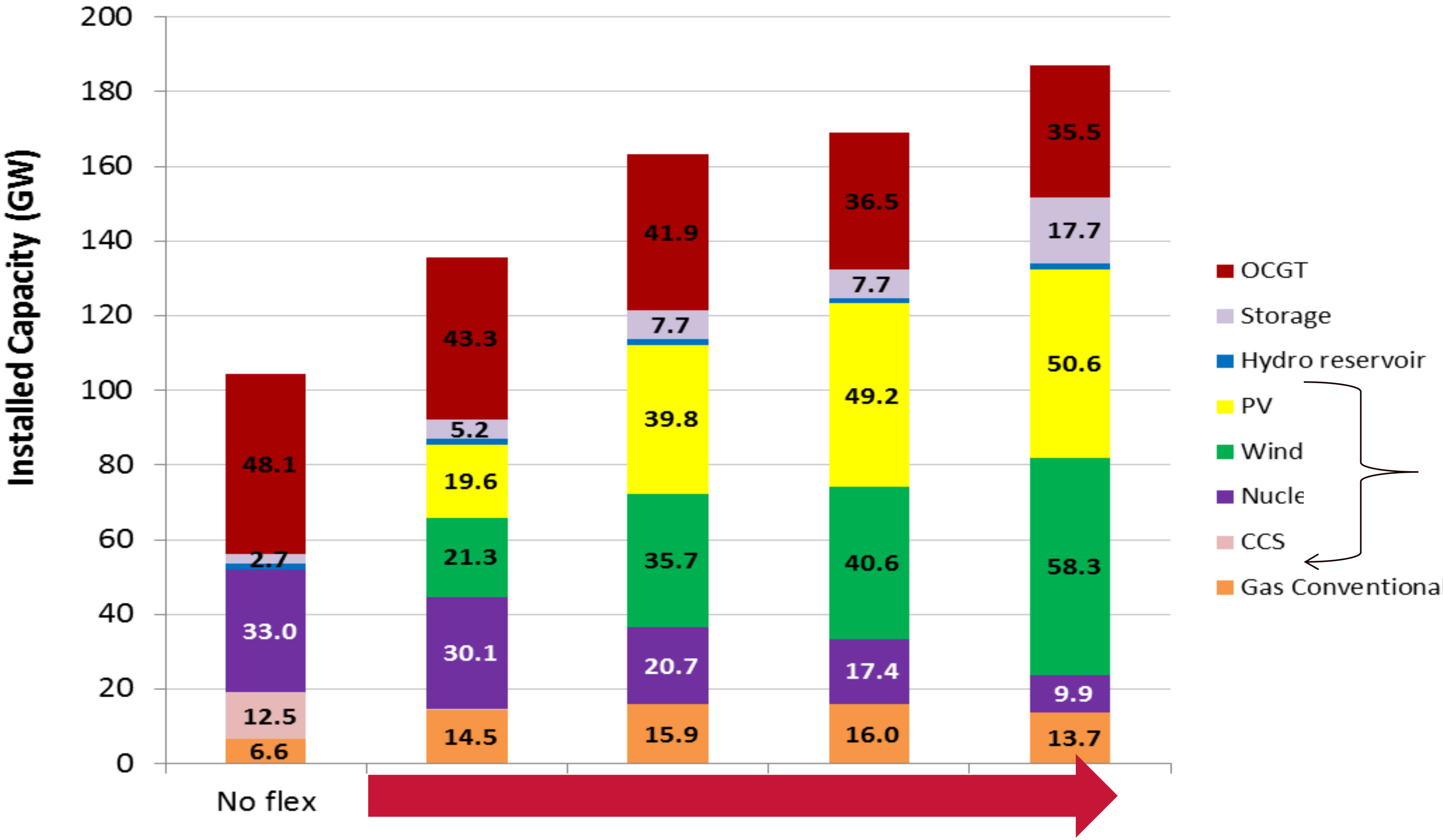
- Energy system capacity planning — Years before delivery
- Long-term supply and storage scheduling — Months to days before delivery
- Day-ahead supply, storage, and demand scheduling — One day to one hour before delivery
- System balancing — Actual delivery: physical supply and consumption (second timescale)

Temporal resolution

IWES – *Integrated, Whole-Energy System model*

Imperial College London

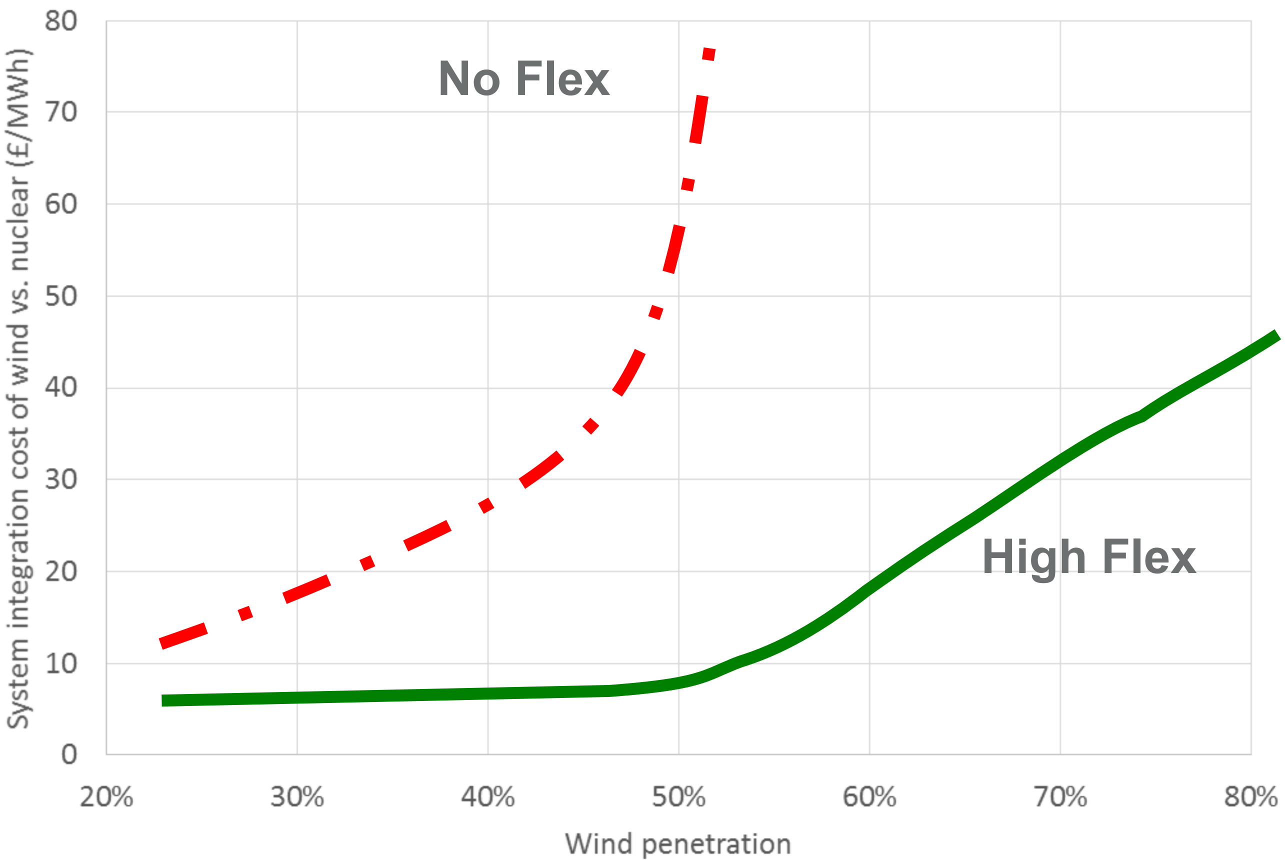
Flexibility – key driver for cost effective evolution to low carbon energy system



Flexibility –Storage & DSR

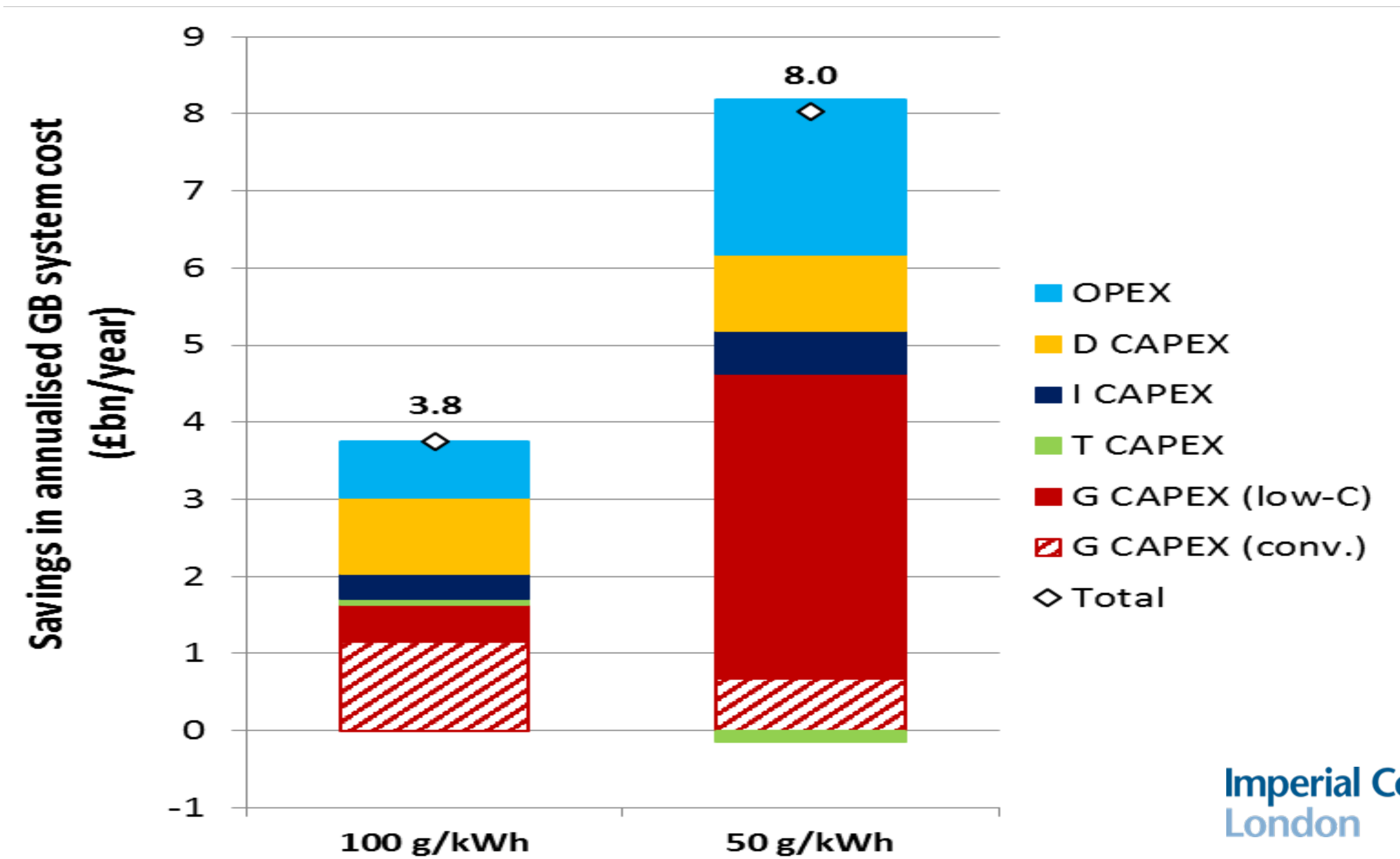
Storage increases the ability of the system to integrate RES

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



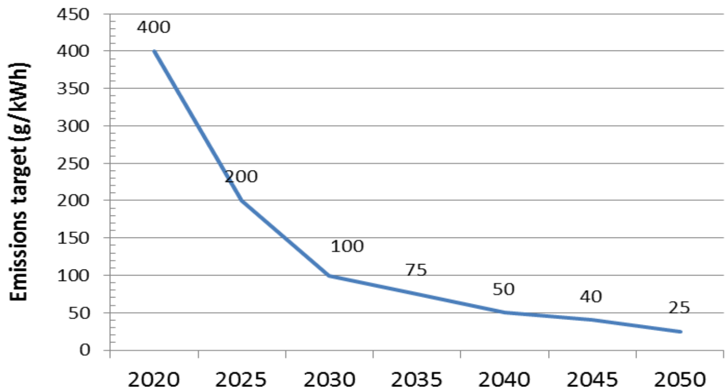
Whole-System costs and <u>competitiveness</u> of RES driven by system flexibility

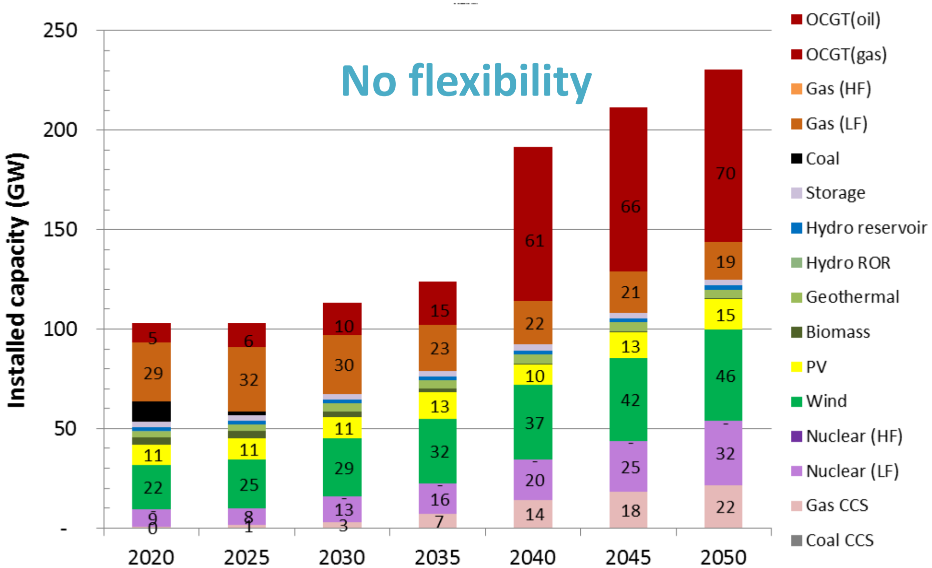
Volume of the market for Storage & DSR post 2030 > £8bn/y



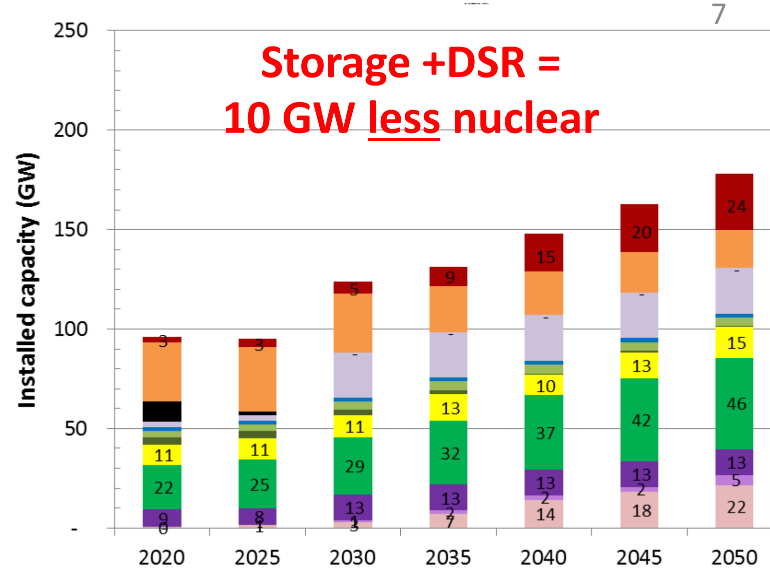
Imperial College London

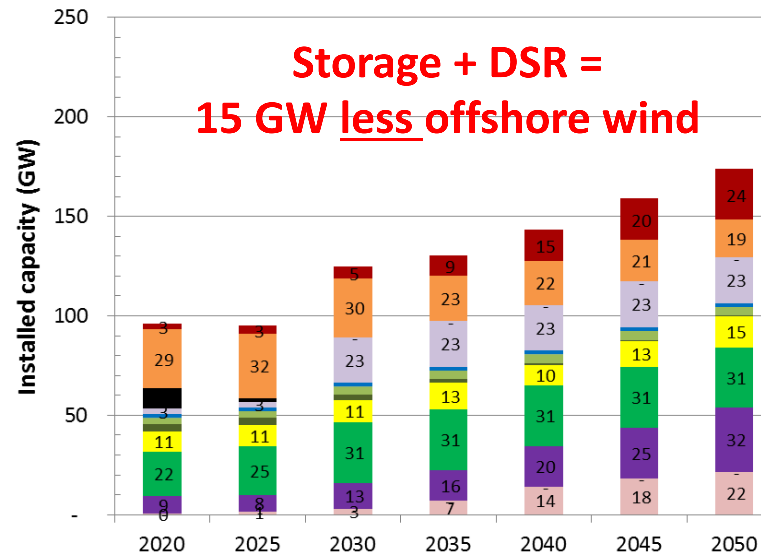
Carbon benefits of flexibility





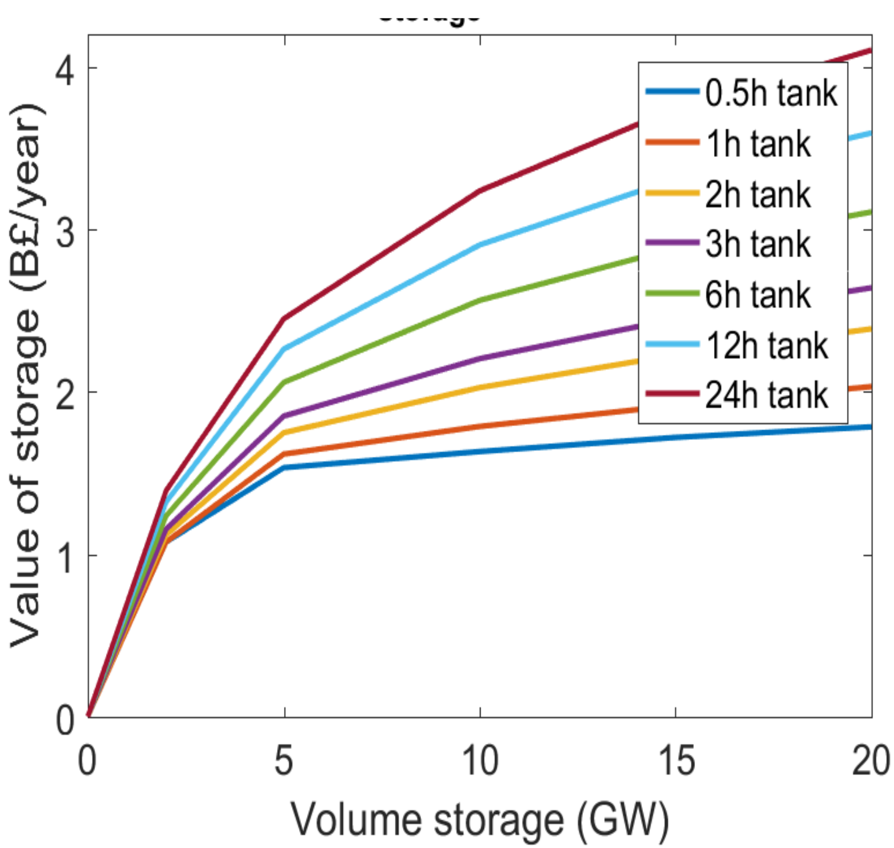
UK scenario

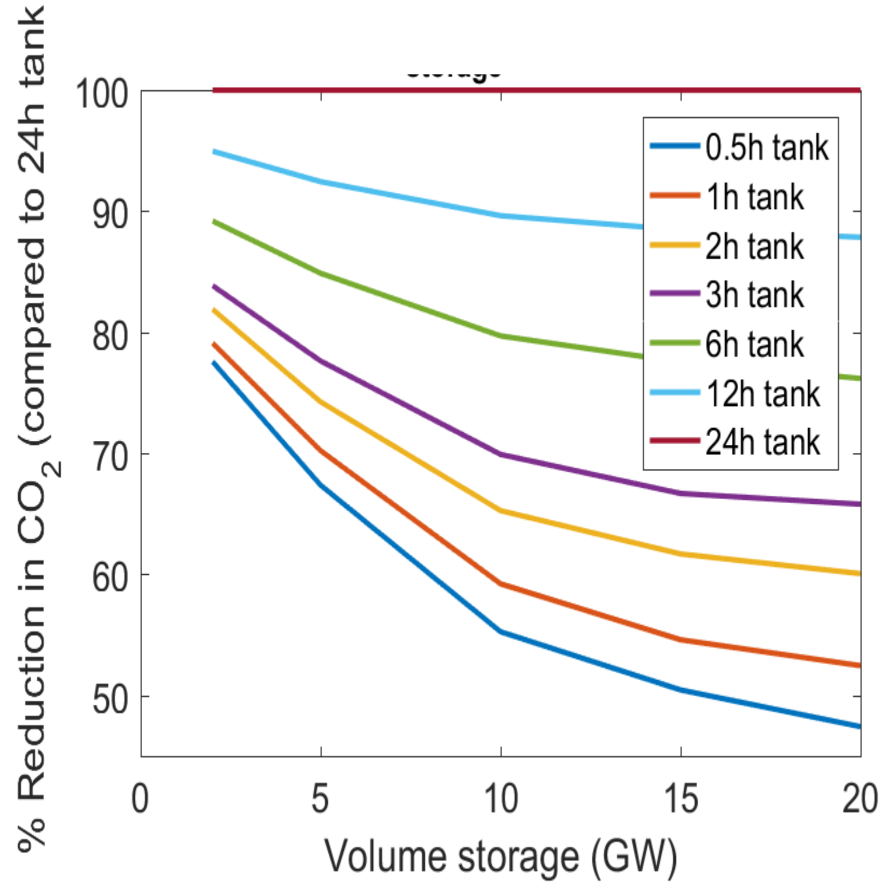




Value of storage with different durations (impact on operation costs and CO2 emissions)

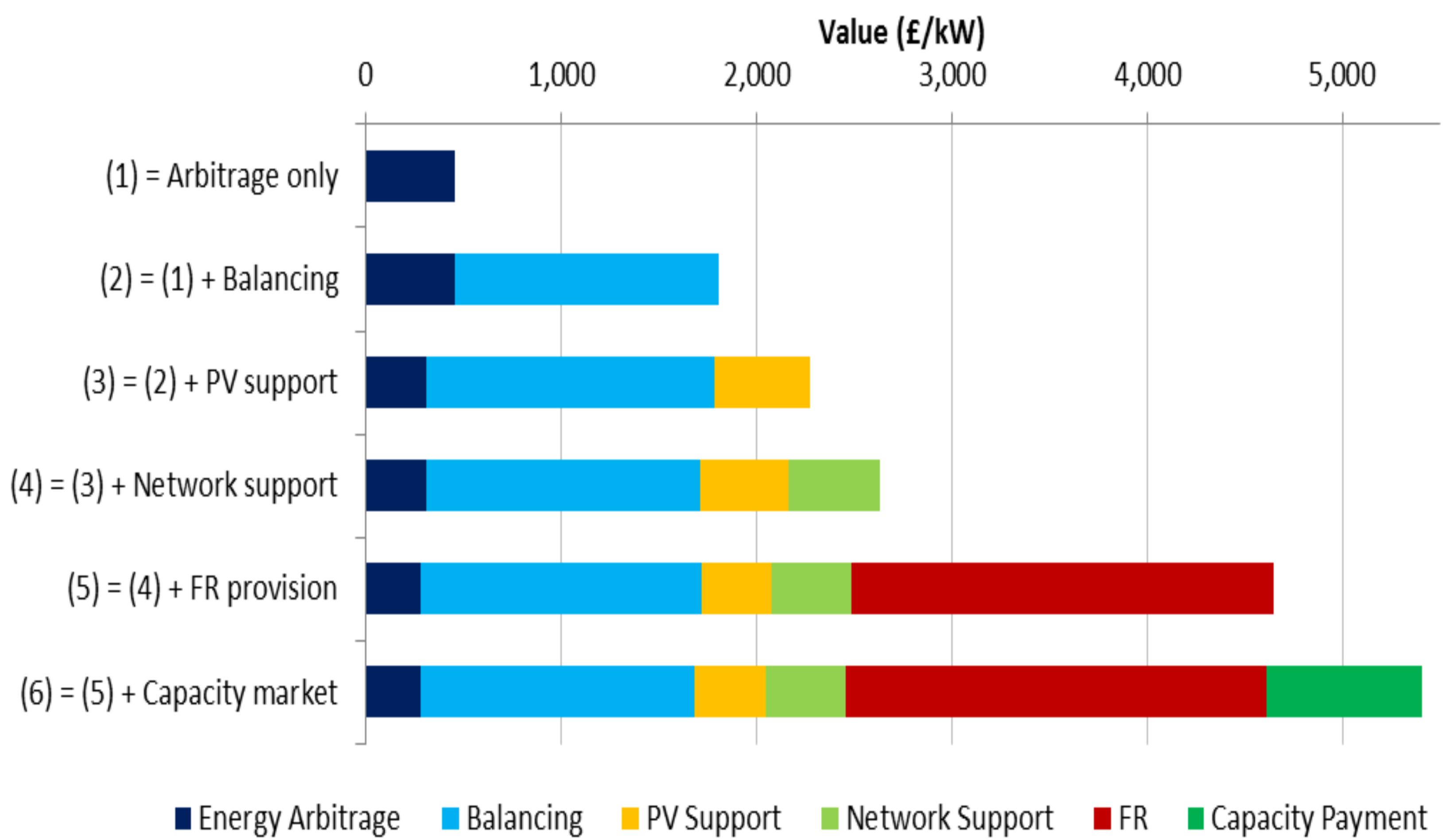
Imperial College London





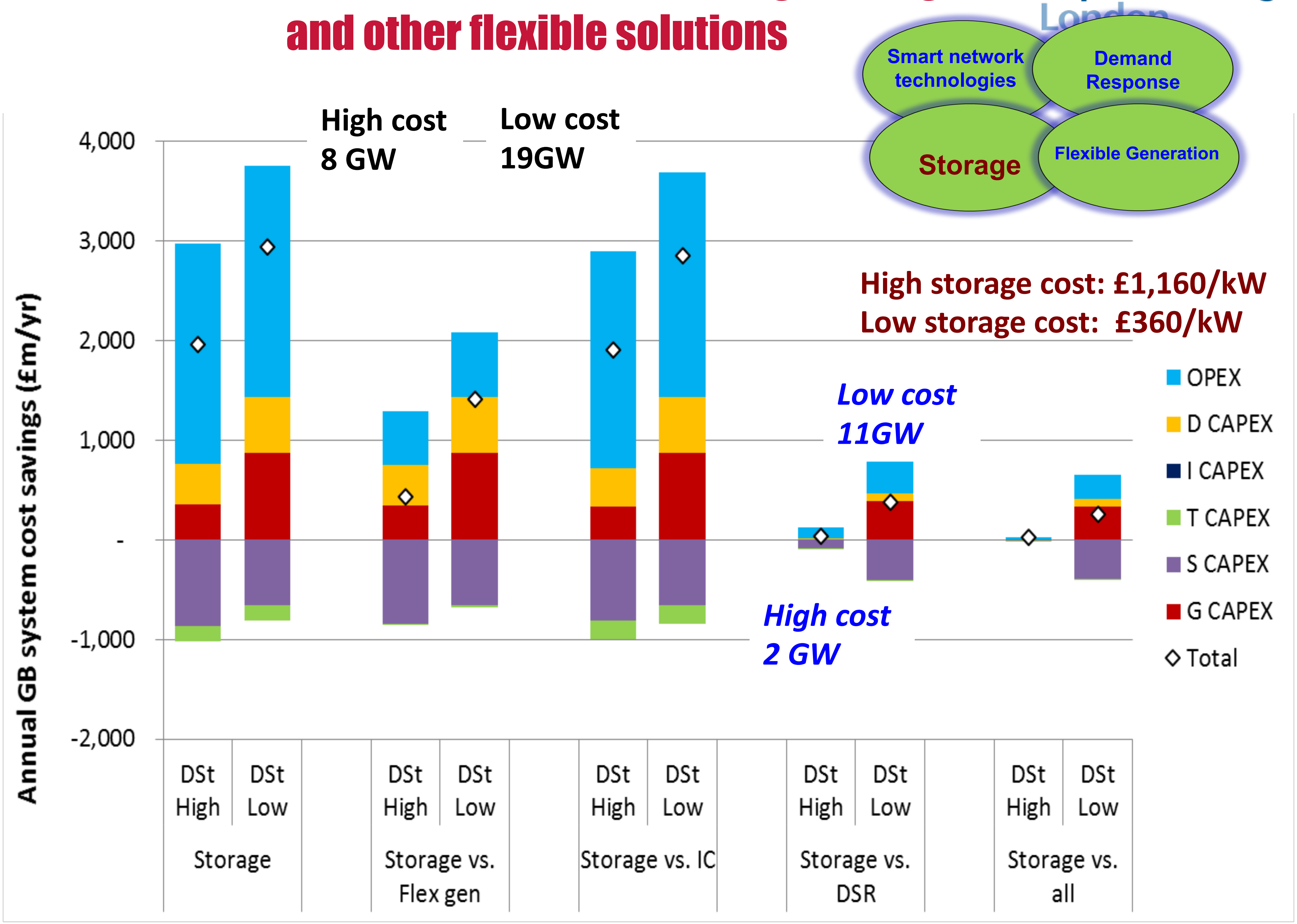
Size of the storage tank has a significant impact for large volumes of deployed storage capacity

Value of energy storage flexibility services: an illustrative case

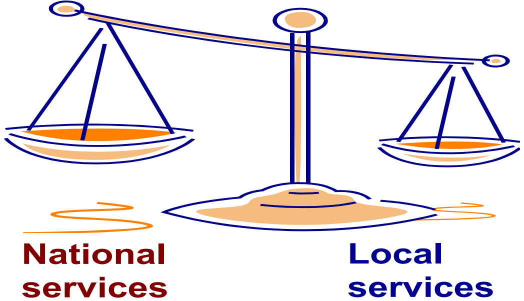


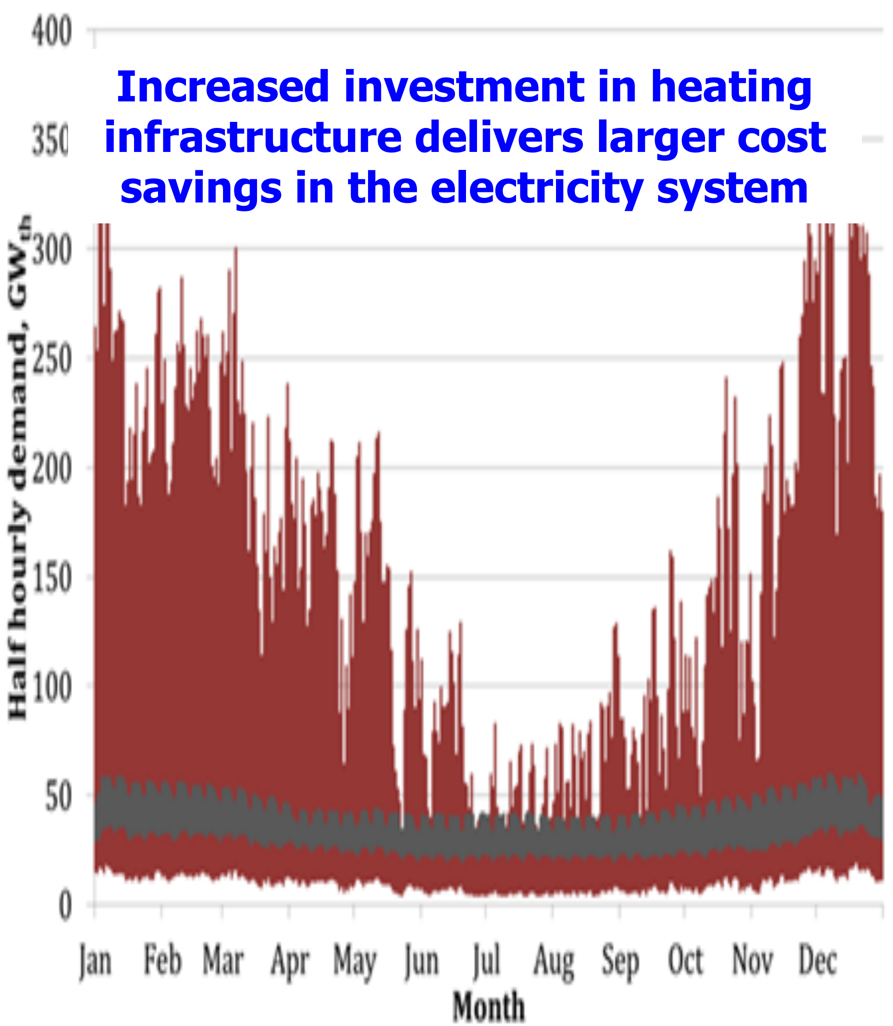
Providing multiple services increases the value of energy storage.
The value implies that storage can reduce the investment and operation cost of the system.

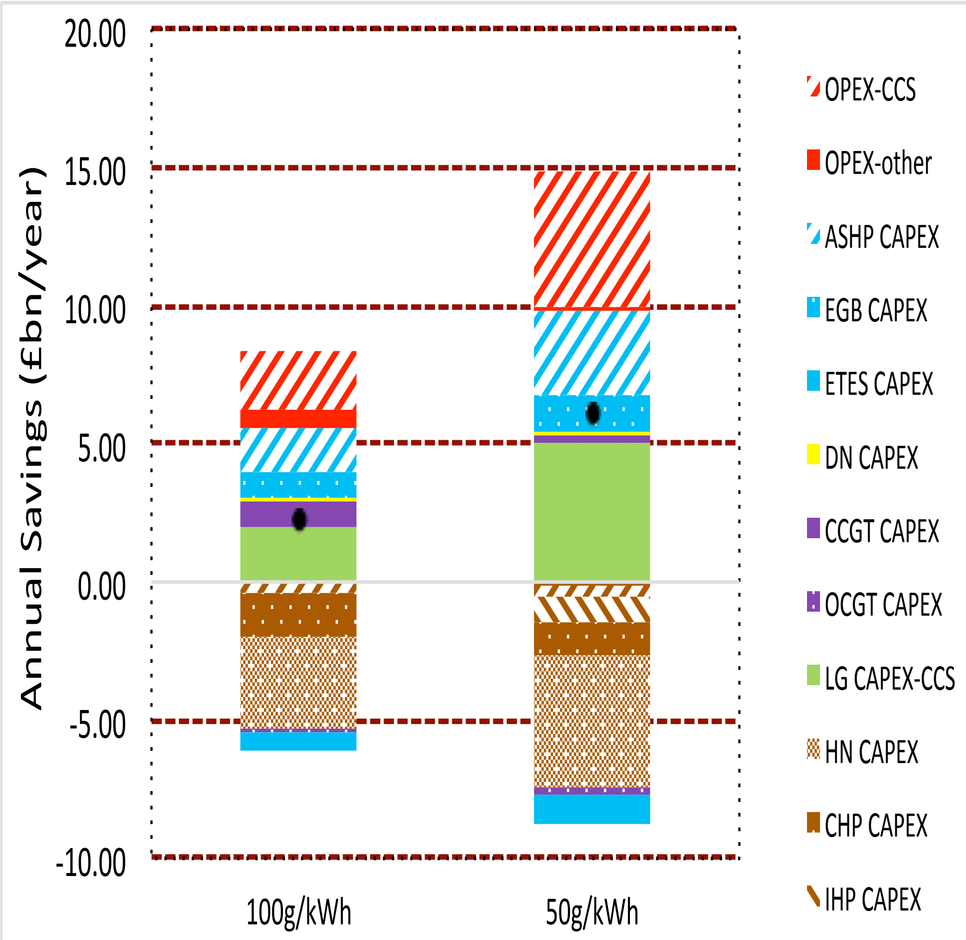
Competition between energy storage and other flexible solutions



How important is the integration of heat, gas electricity, sectors?



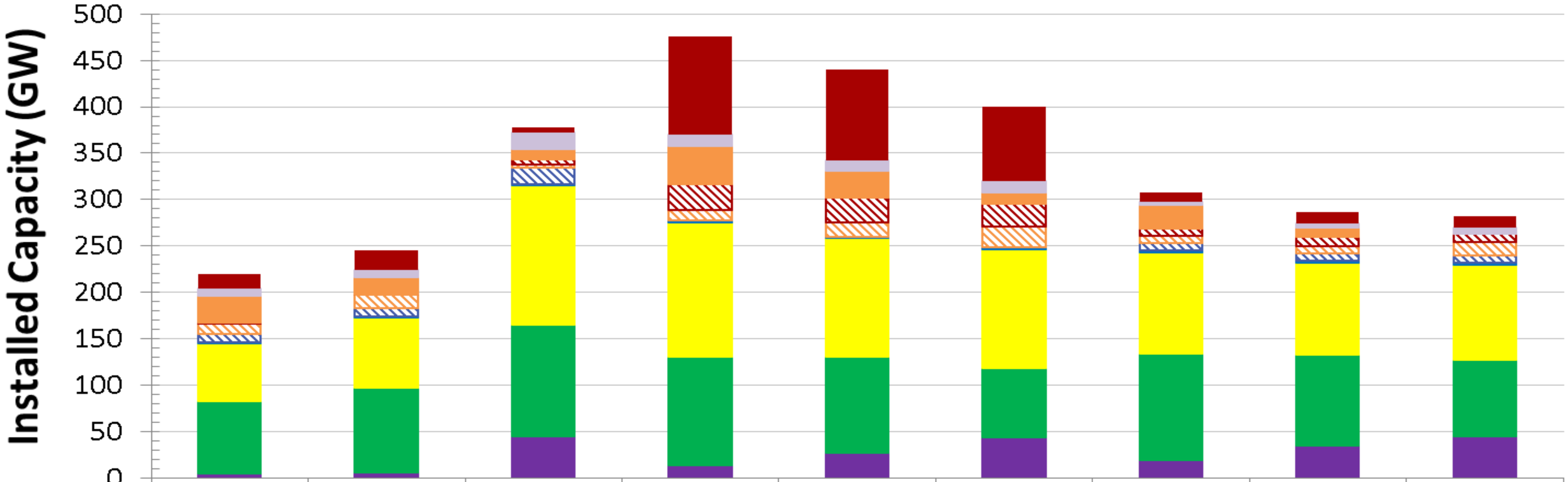




Flexibility - significant opportunity from integrating heat / cooling, gas, electricity, transport, water infrastructure

Optimal portfolio of power generation and storage capacity in different pathways

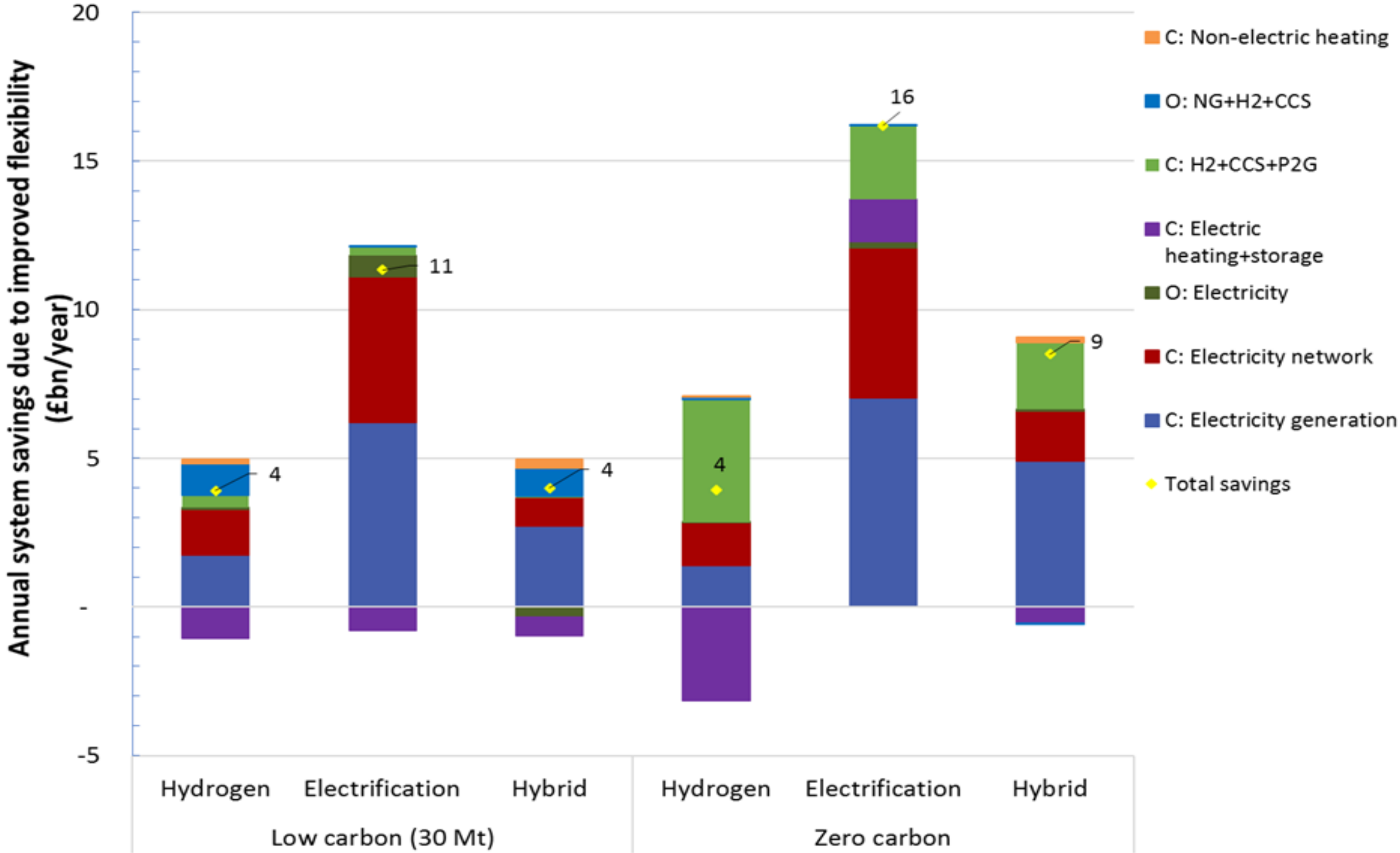
Imperial College London



	Hydrogen			Electric			Hybrid		
	H2 [30]	H2 [10]	H2 [0]	Elec [30]	Elec [10]	Elec [0]	Hybrid [30]	Hybrid [10]	Hybrid [0]
OCGT	15	21	6	106	98	79	9	11	13
Storage	7	8	18	12	12	12	4	4	6
CCGT	30	19	11	41	28	13	26	11	0
H2 OCGT	0	0	5	27	27	24	8	10	9
H2 CCGT	12	14	3	12	15	23	7	8	14
District CHP	8	9	18	0	0	0	8	8	8
Hydro	1	1	1	1	1	1	1	1	1
PV	63	76	150	146	128	129	110	99	103
Wind	77	92	120	117	104	74	115	98	82
Nuclear	5	5	45	13	27	43	19	35	45

A stricter carbon target tends to require more firm low carbon generation

Value of flexibility in 2050 under different energy heat decarbonisation pathways

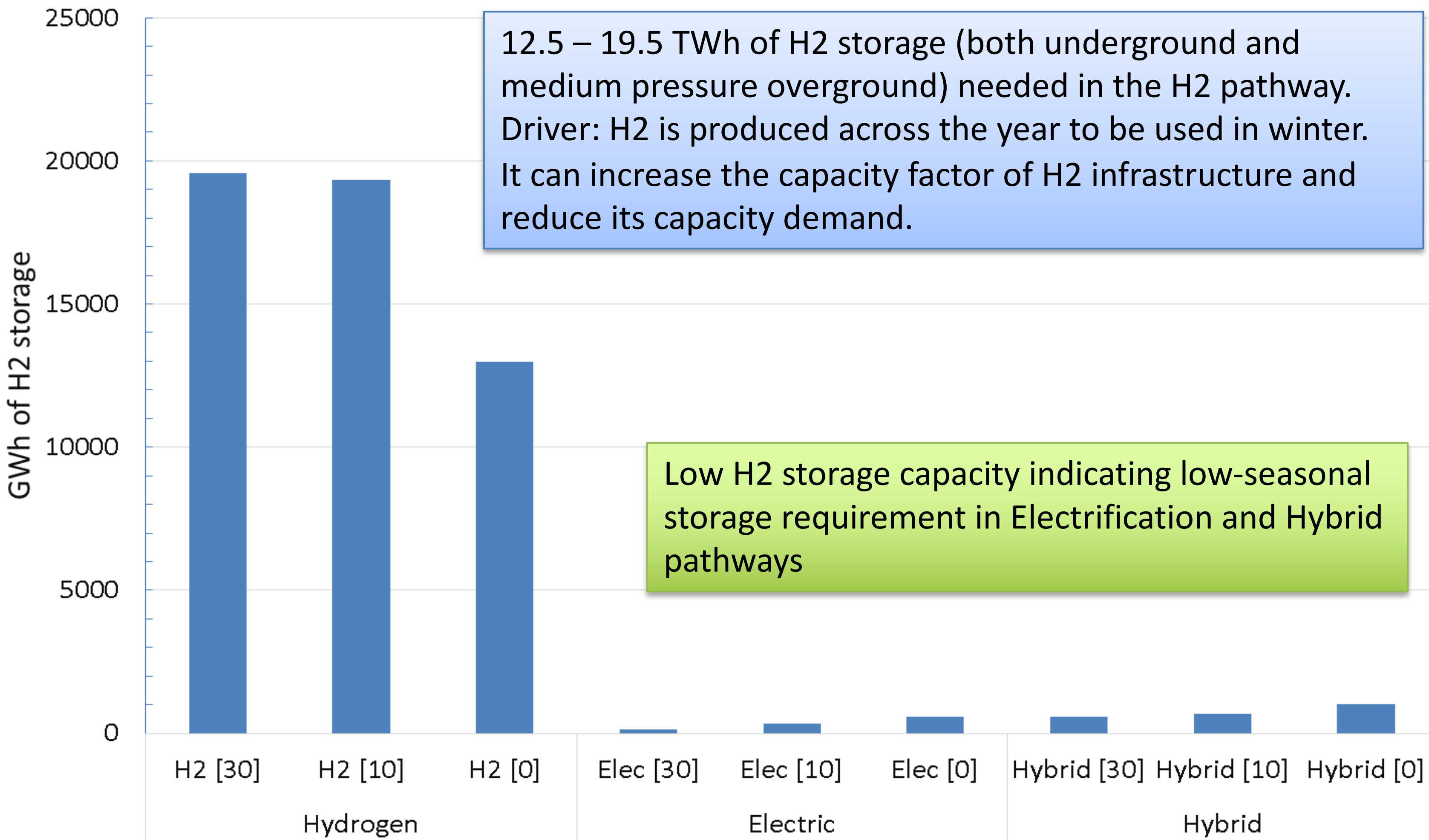


Energy storage can reduce cost of operation of and investment in energy infrastructure.
The value is system specific; higher with stricter carbon target.

https://www.theccc.org.uk/publication/analysis-of-alternative-uk-heat-decarbonisation-pathways/

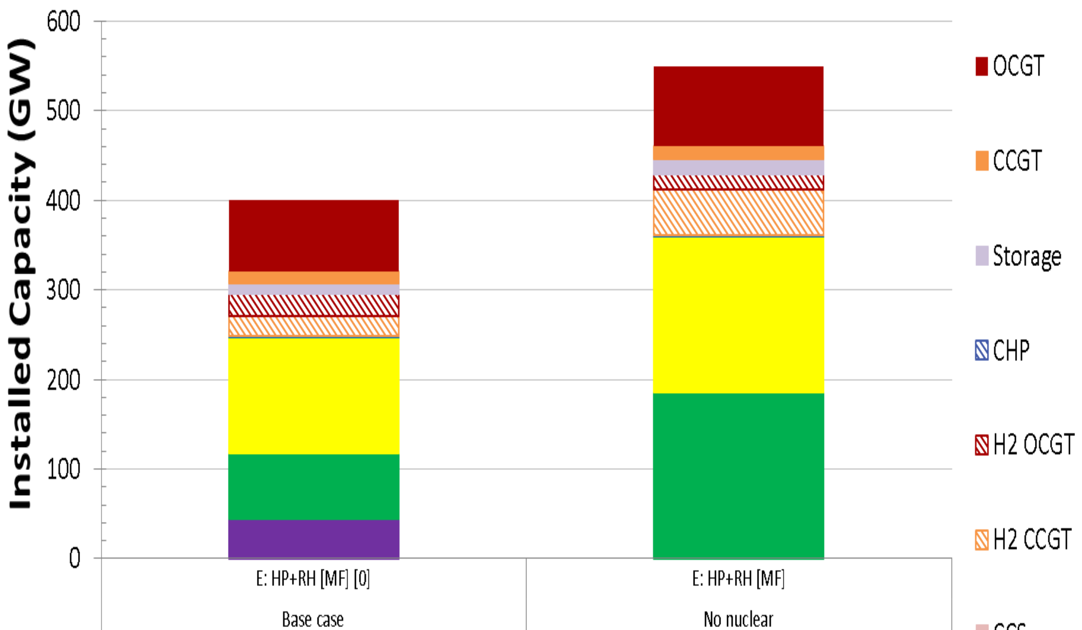
Hydrogen storage in different pathways

Imperial College London

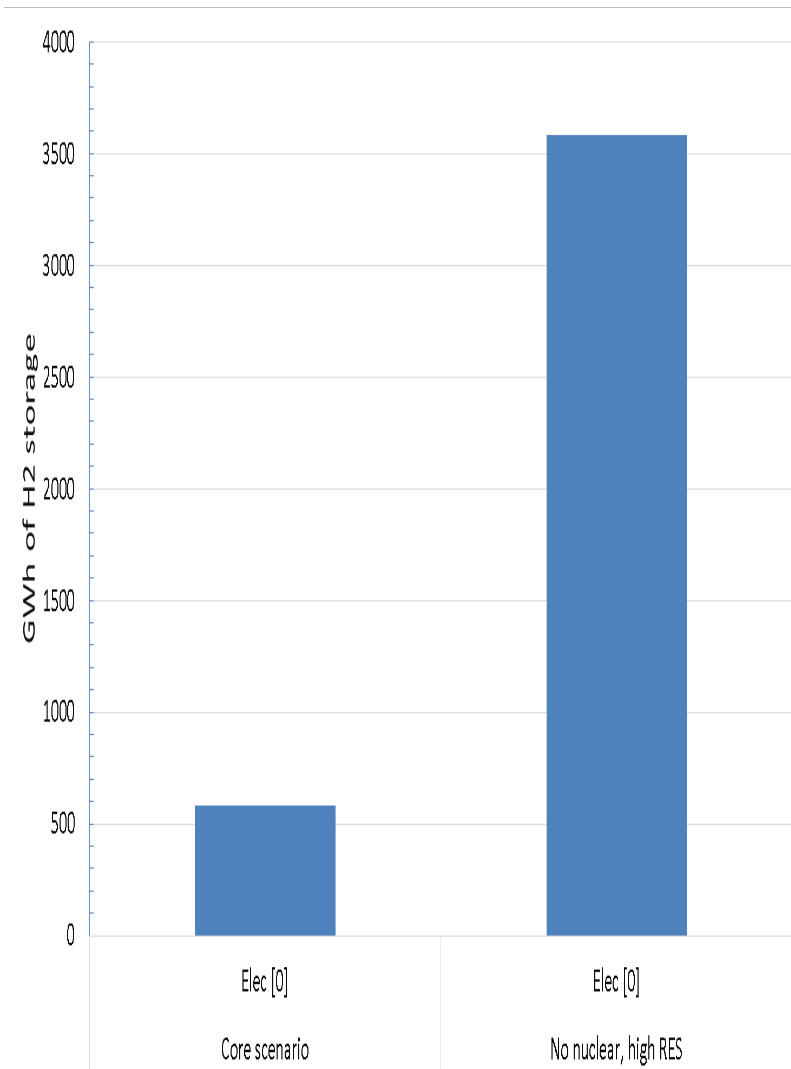


Firm Low Carbon Generation: Renewables + Medium/Long term storage

Imperial College London



	E: HP+RH [MF] [0] Base case	E: HP+RH [MF] No nuclear
OCGT	79	88
CCGT	13	14
Storage	12	18
CHP	0	0
H2 OCGT	24	16
H2 CCGT	23	51
CCS	0	0
Hydro	1	1
PV	129	175
Wind	74	185
Nuclear	43	0

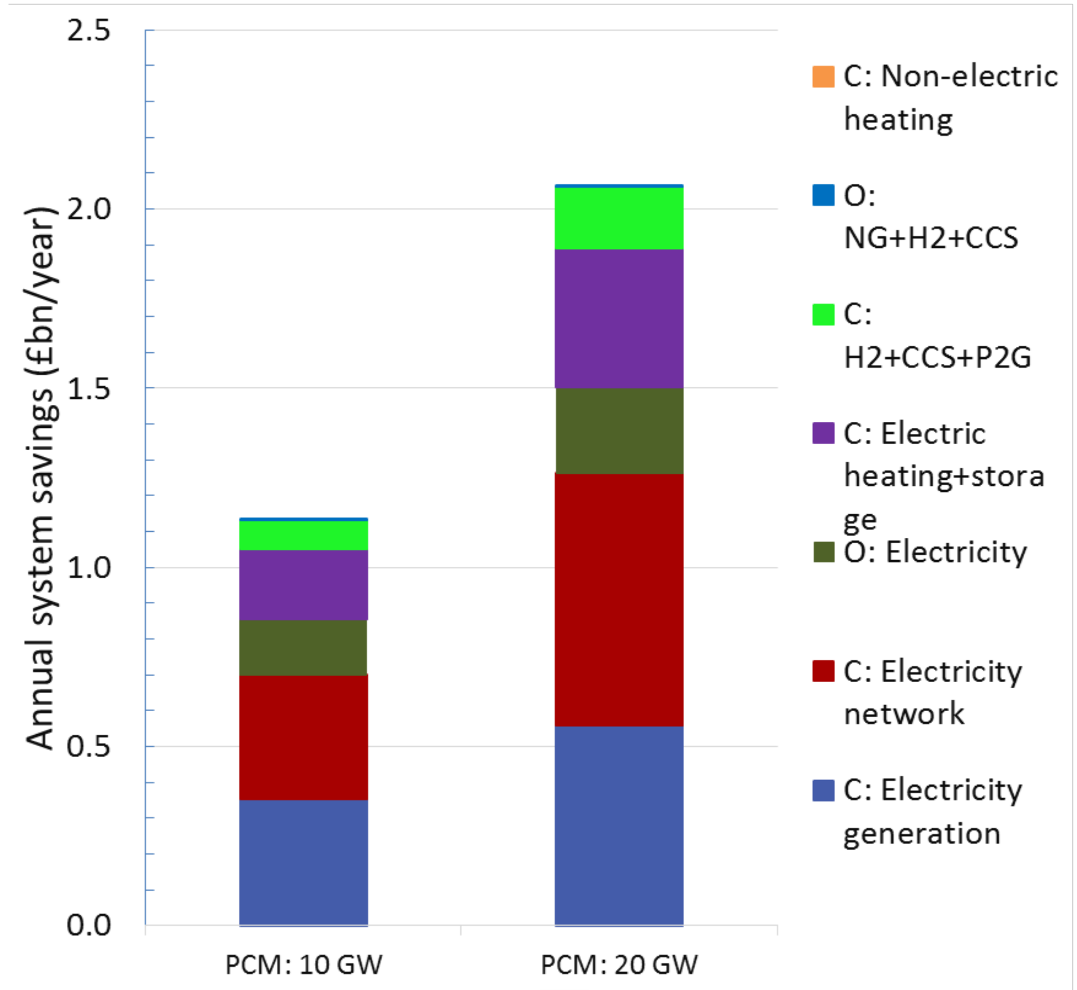


Note:

- In 0 Mt, CCGT and OCGT will run on biogas (carbon-neutral)
- Source: ICL (2018) Analysis of Alternative UK Heat decarbonisation Pathways. A report for Committee on Climate Change.

Value of smart TES

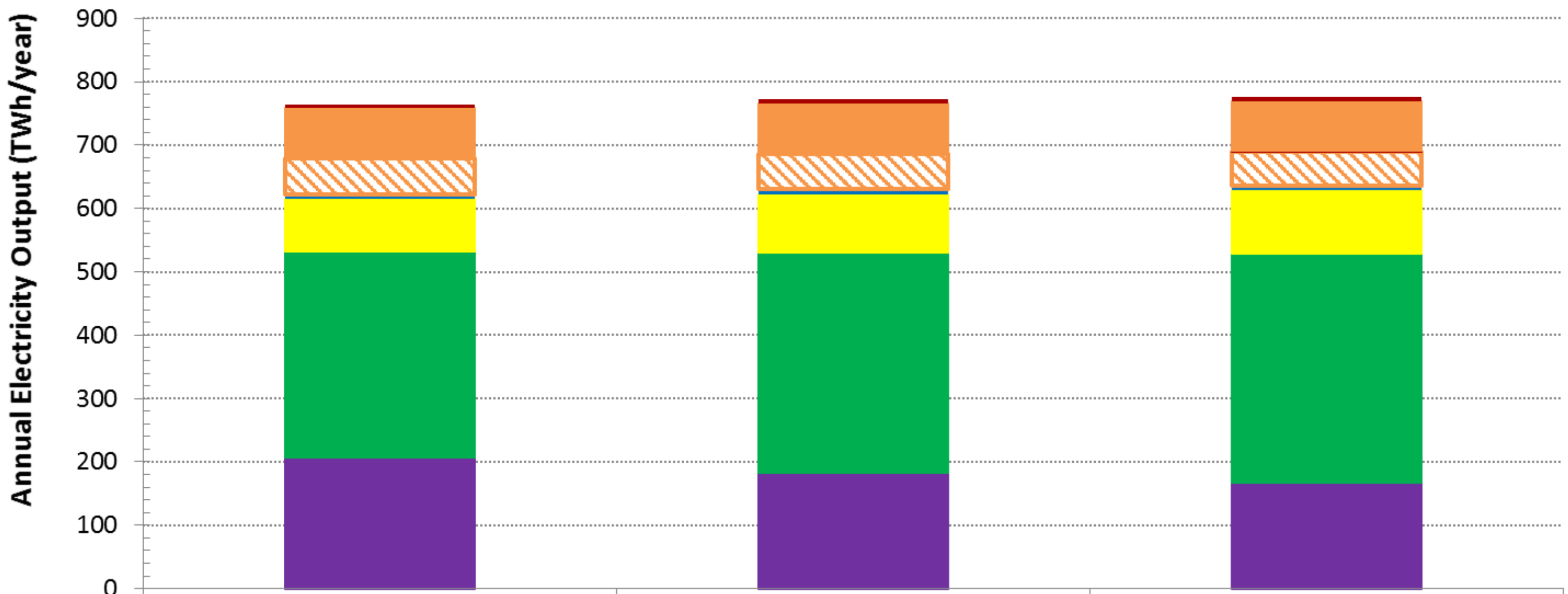
- Scenario
  - 2050 energy system
  - Electrification of heat and transport (light vehicles)
  - Carbon target
  - Very large energy storage capacity
- Counterfactual
  - No Active Building (low flexibility)
- Analysis
  - Flexibility provided by smart PCM-based TES (10,20 GW)
    - Convert electricity to heat
  - Gross system value
    - £103-£113/kW per year



Significant value of TES

Changes in the optimal electricity generation production due to PCM-based TES

Imperial College London

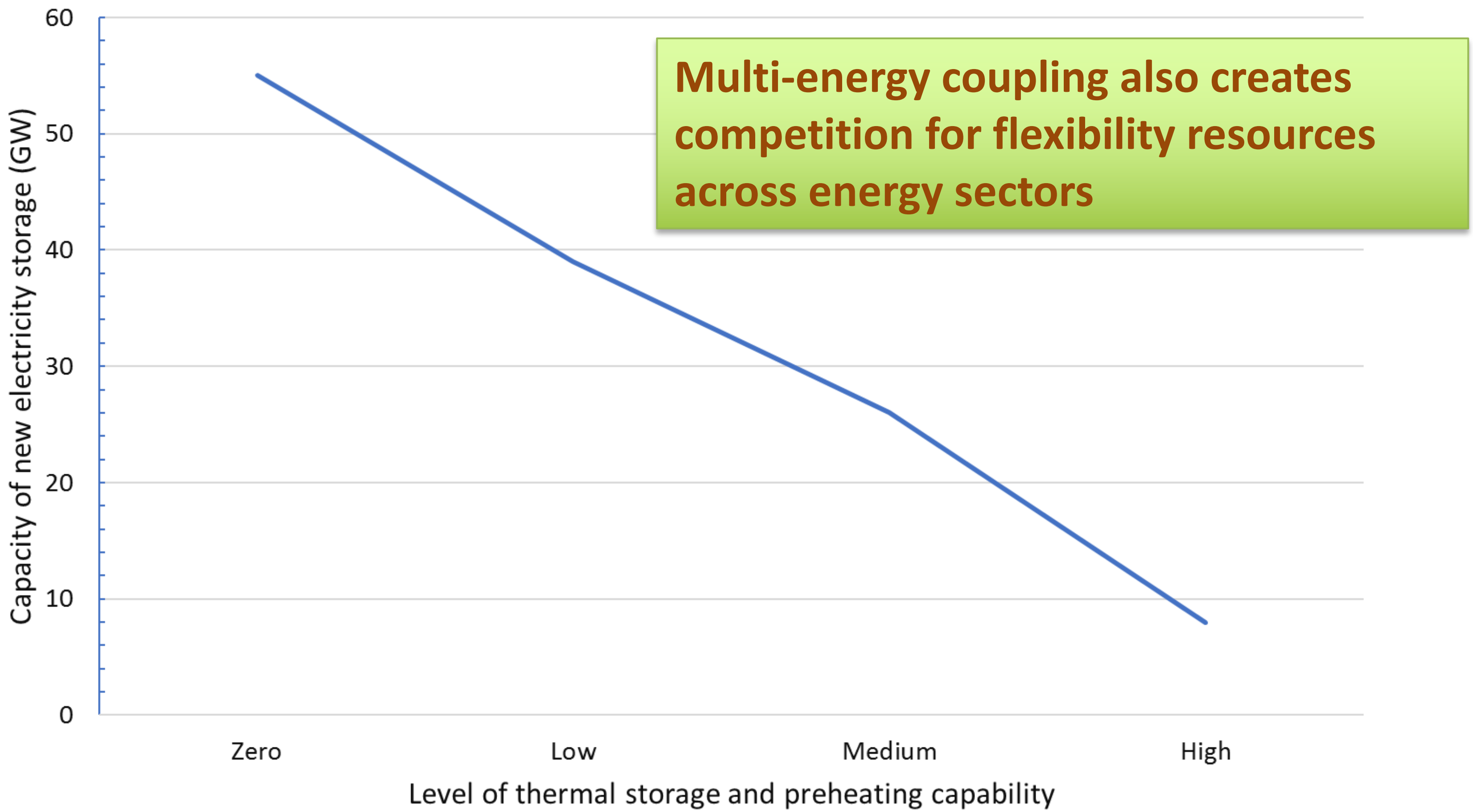


	No PCM	PCM: 10 GW	PCM: 20 GW
OCGT	7	7	7
CCGT	78	79	79
H2 OCGT	2	2	2
H2 CCGT	56	55	53
Hydro	8	8	8
PV	83	93	100
Wind	324.49	347	361
Nuclear	207	183	168

TES reduces the need for firm low carbon generation (nuclear)

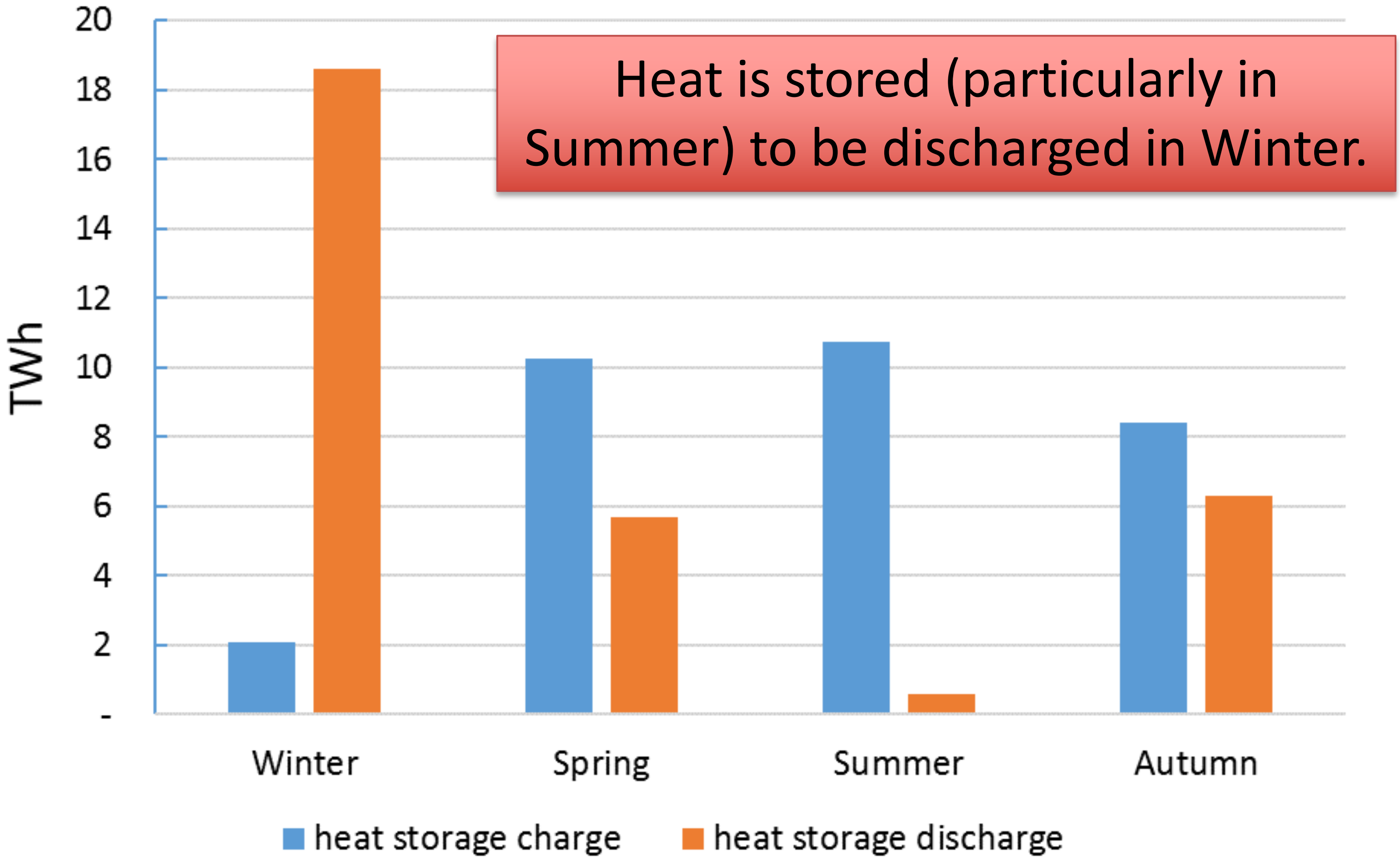
Thermal storage or electricity storage ?

Imperial College London



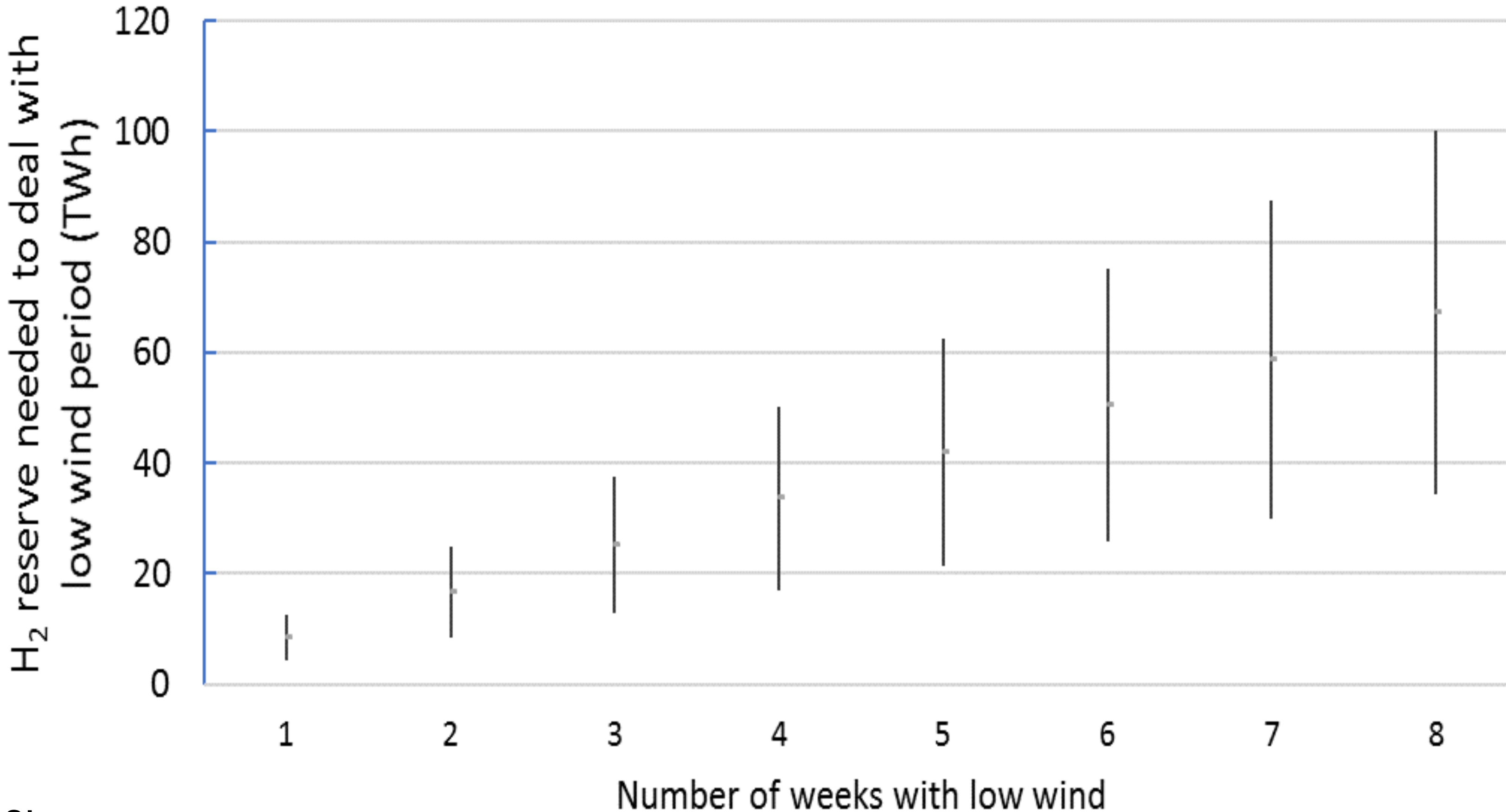
Number of household: 34.3 M
Thermal storage: 1.7 kWth/household

Seasonal TES charging and discharging pattern



*Scenario with 20 GW TES

Additional H2 storage to deal with a prolong low wind period



Notes:

- Scenario: heat decarbonisation via electrification with 0Mt carbon target
- The range of results reflects the variability of wind that was expected to be available
- The "missing wind" is filled by storing the excess wind via electrolysers in the form of hydrogen which is used by H2 CCGTs
- Gas / H2/ electricity Interconnection

Findings

- Energy storage – critical for supporting cost effective energy system decarbonisation
- Providing multiple services increases the value of energy storage
  - Firm capacity (for security)
  - Arbitrage (short to long term)
  - Balancing services
  - Network reinforcement
  - Low carbon agenda (managing RES)
- Medium/Long duration energy storage could displace firm-low carbon generation
- The value is system specific
  - Whole-system (multi-energy vectors) approach evaluation
  - Synergy and competition with different energy storage technologies and other flexibility technologies
  - Dealing with extreme weather conditions