UNIVERSITY OF BIRMINGHAM | COLLEGE OF ENGINEERING AND PHYSICAL SCIENCES

Supergen | Energy Storage

UK Roadmap for Energy Storage Research and Innovation

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IGI Resilient Cities theme lead

BIRMINGHAM ENERGY INSTITUTE | THE INSTITUTE FOR GLOBAL INNOVATION

Storage

What it is:

- A buffer between production and consumption
- Can be placed across the system, and can be of different forms/scales
- Has a capital cost to set up, and running costs

What it does:

- Balances supply and demand
- Will affect production and consumption quantities and prices
- Use it to reduce the 'system' cost

The 'optimum' level of storage will depend on the system, and affect the system.
An independent owner/operator of storage will seek to maximise their profit.

‘Conventional’ energy storage

Coal: ~40 TWh,
down from 125 TWh in 2005
Gas: ~30 TWh,
down from 55 TWh in 2005
Oil: 135 TWh, stable

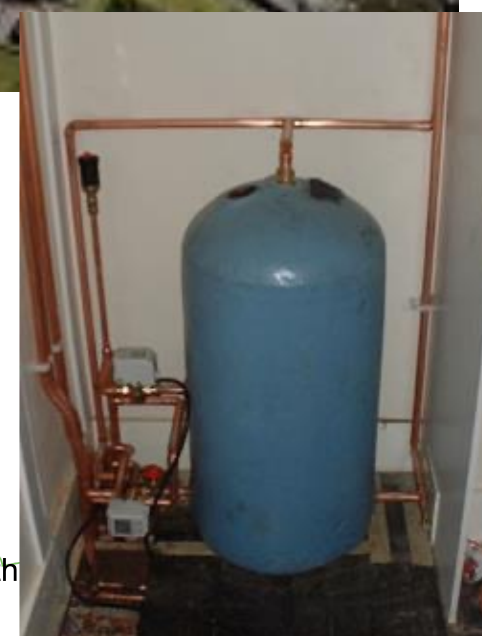
(Source: Wilson, UoB, 2020)

1Mt coal = 3,000 GWh_e
(about two months output at 2GW)

Pumped hydro storage:
total UK = 28 GWh_e

Hot water cylinder: in 40% of homes, down from 62% in 2007

one tank = 6 kWh_{th};
15m tanks = 90 GWh_{th}



Reasons for storing energy

Storing energy at large scale has become lower priority, with higher diversity in supplies, interconnection to other markets, and reducing demand.

Old school priorities

Purpose	Description
Geopolitical security	Manage disruptions to imported energy.
Economic security	Fuel bought in advance hedges against price swings.
System resilience	Provide security of energy supply against system shocks.
Meeting demand	To meet peak demand for energy services.
Supply-side efficiency	Allow producers to run efficiently, and reduce curtailment.
Coupling energy services	Enable the transformation of energy to another service.
Efficient network utilisation	Maximising use of infrastructure.
System stability	Managing short-term supply/demand variations.

New wave

Increasing RES has meant higher priority for short timescale storage.

But dominance of RES and increasing electrification will flip priorities again… and again.

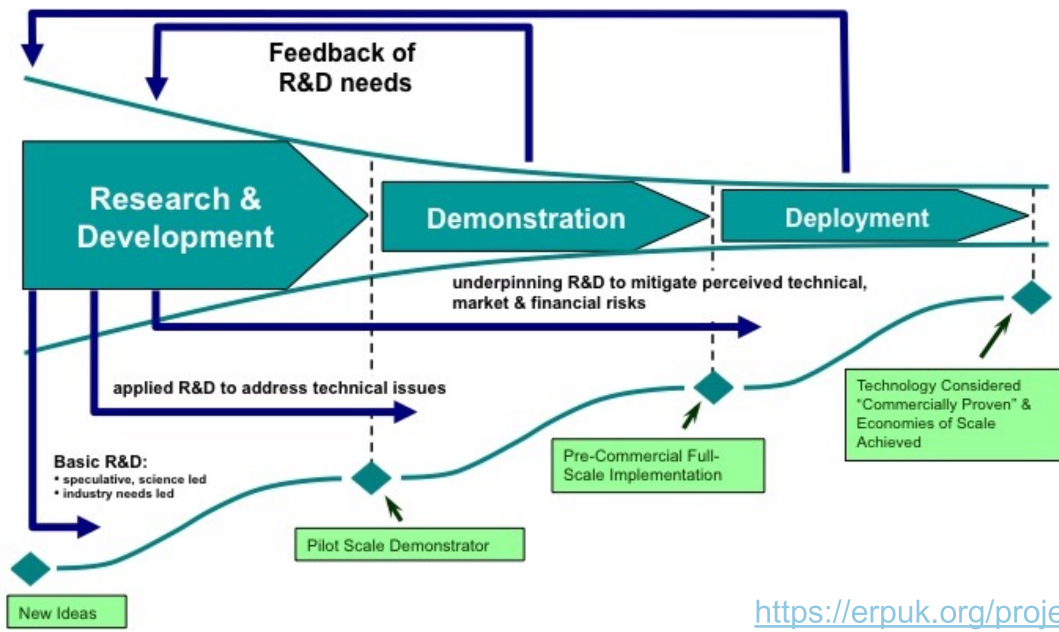
The roadmap

Purpose

- Inform research agenda: Government and UKRI funding and policy
- Develop a shared vision for energy storage innovation in the UK: for those working in the field, but also those in related areas

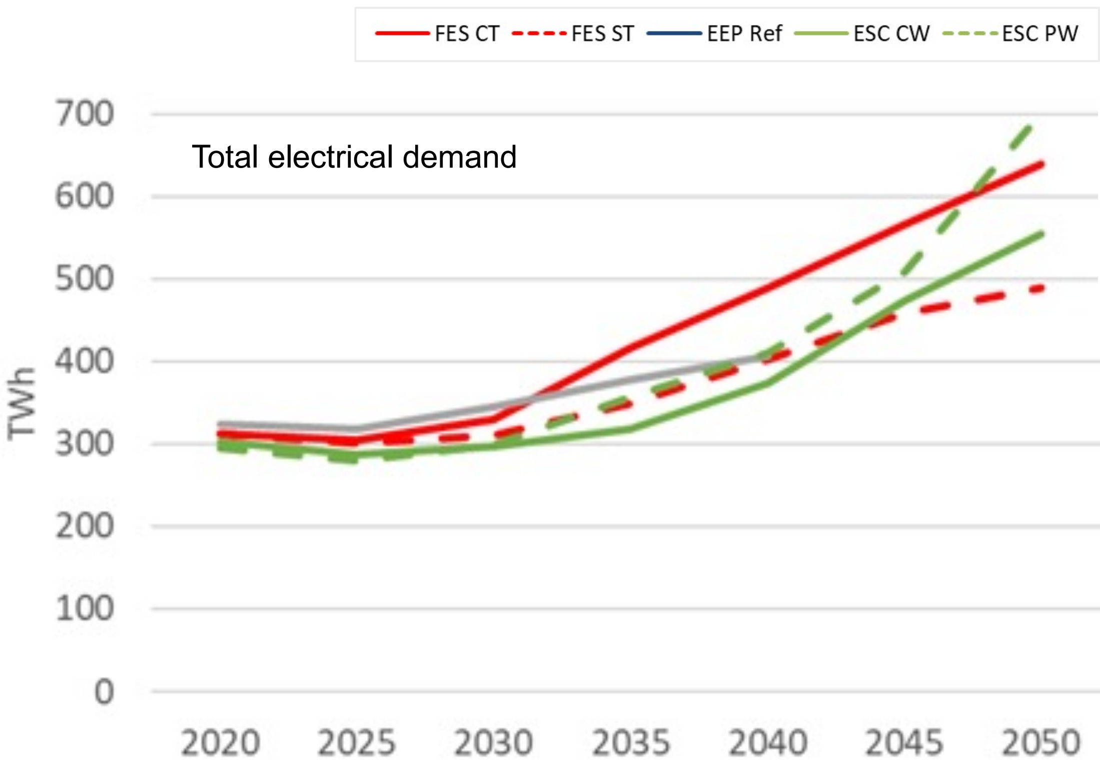
Scope

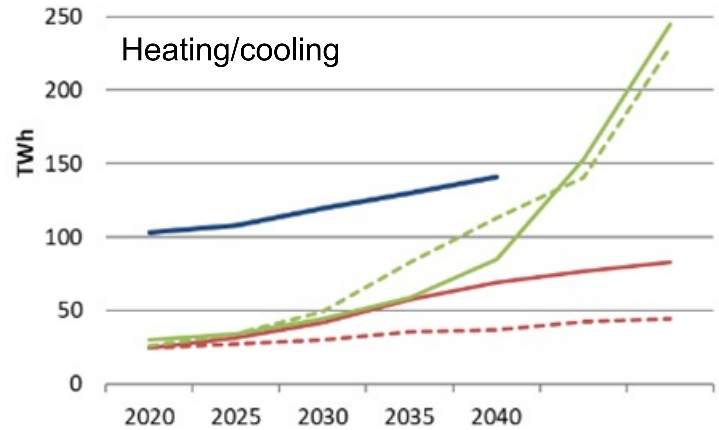
- A high-level roadmap of how energy storage could integrate into future energy systems, considering possible scenarios
- Research and innovation across technical and non-technological challenges

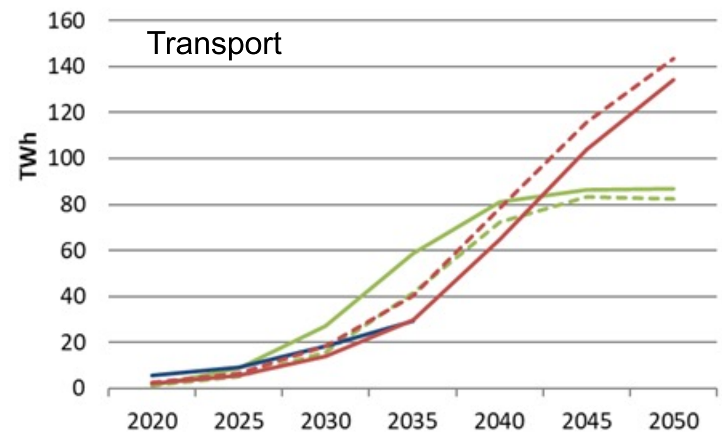


https://erpuk.org/project/uk-energy-innovation-2/

Energy system scenarios – demand side

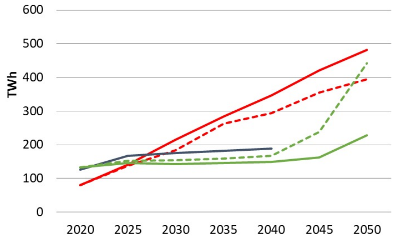




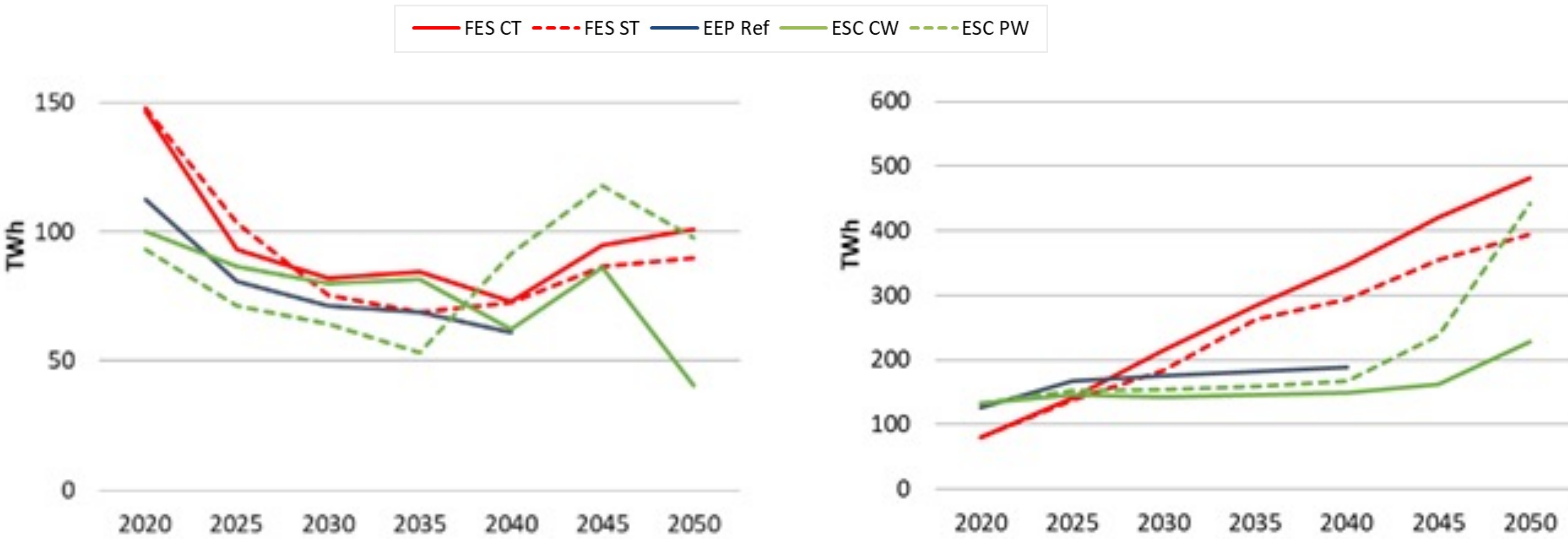


Demand for electricity will increase, to provide power, transport and heat

Scenario data from National Grid 'Future Energy Scenarios 2020'; ES Catapult, 'Innovating to Net Zero' (2020), BEIS, 'Energy and emissions projections' (2020)



stem scenarios – supply side



Flexible generation

Wind + solar

Scenario data from National Grid ‘Future Energy Scenarios 2020’; ES Catapult, ‘Innovating to Net Zero’ (2020), BEIS, ‘Energy and emissions projections’ (2020)

General energy system needs for flexibility

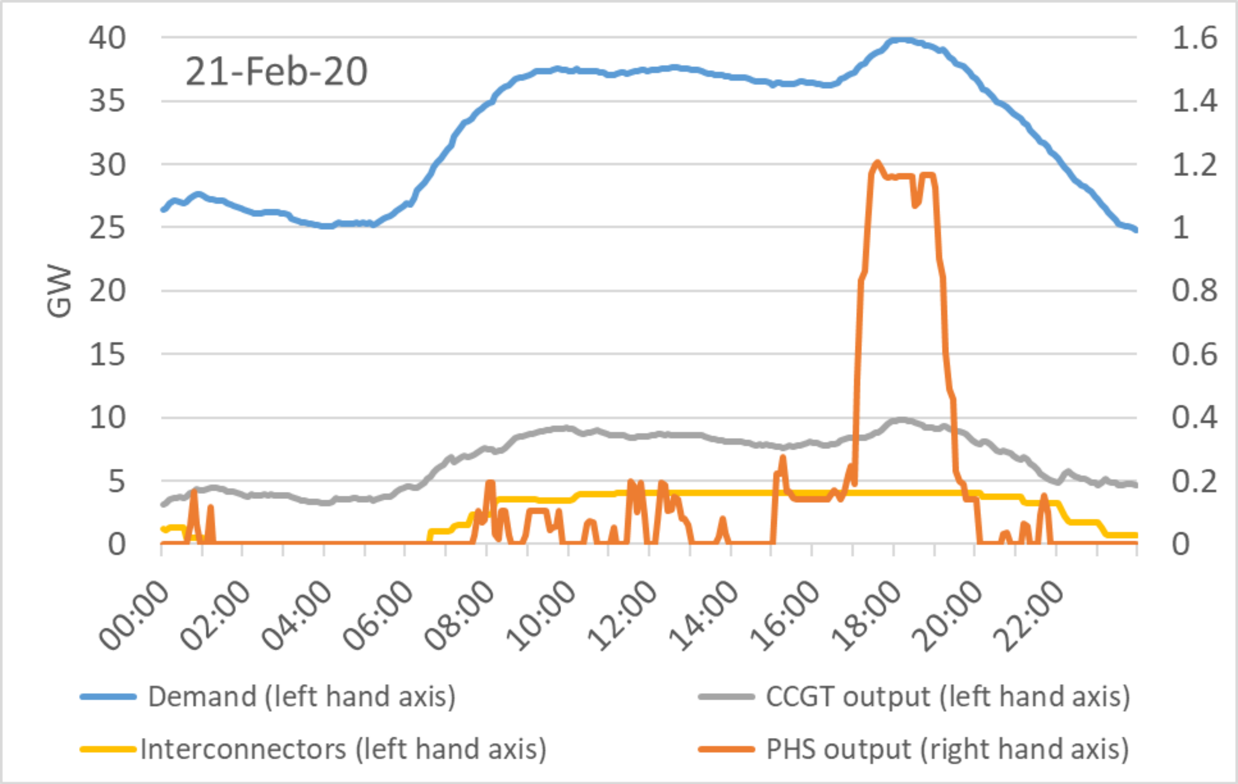
Timescale	Challenge
Seconds	Renewable generation introduces harmonics and affects power supply quality. Reduced inertia from less rotating machinery.
Minutes	Rapid ramping to respond to changing supply (wind, PV) and demand (EVs, HPs).
Hours	Increasing daily peak in electricity demand for heat and EVs.
Hours - days	Variability of weather affecting wind and PV generation.
Months	Increased use of electricity for heat leads to strong seasonal demand profile. Seasonal variability affecting wind and PV generation.

Electricity system flexibility

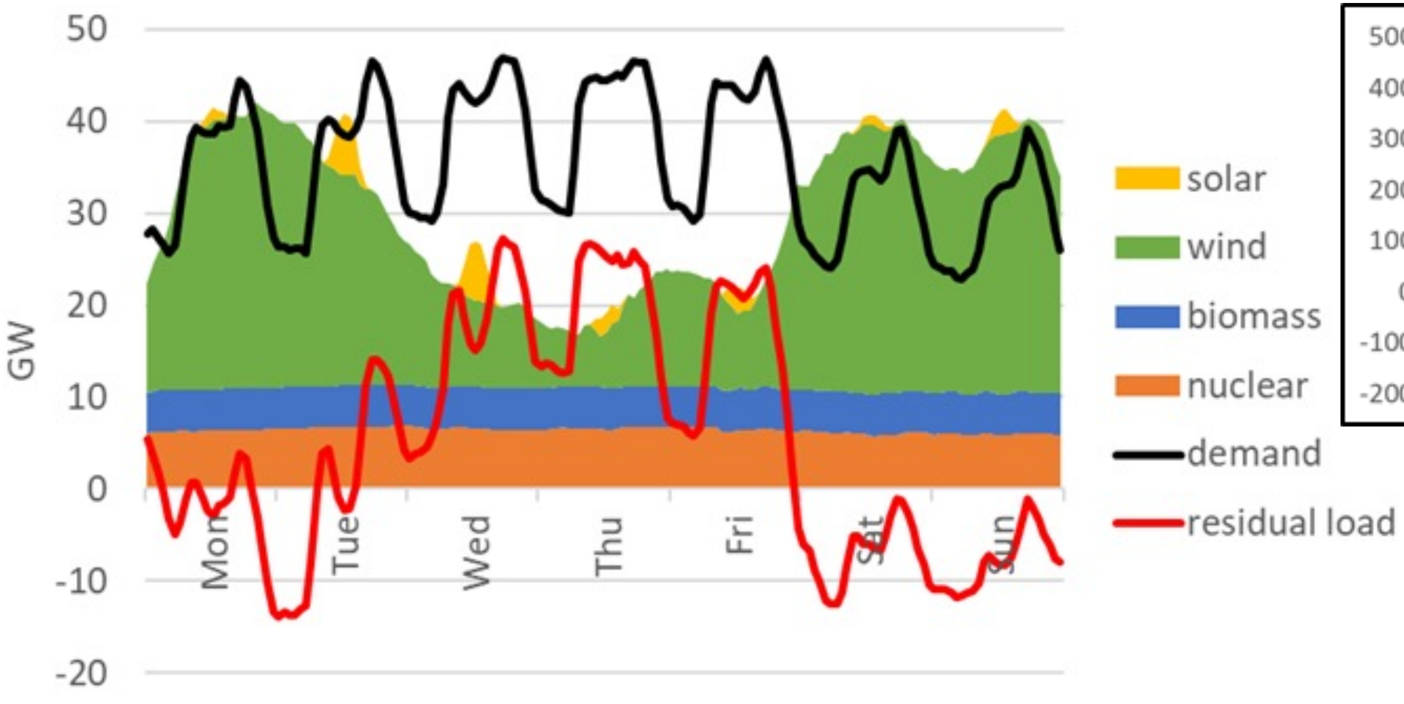
Most electricity system flexibility in the UK has come from non-nuclear thermal generation capacity, fuelled by natural gas or coal

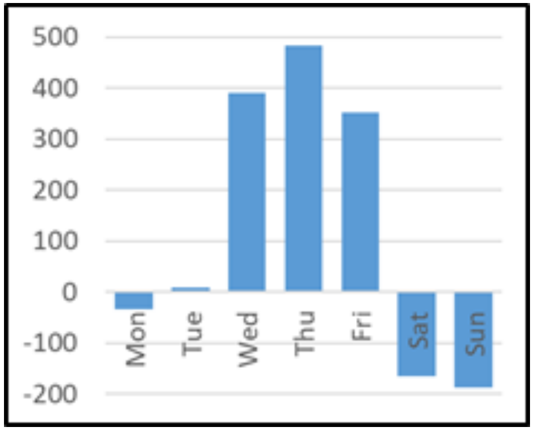
Interconnectors also provide 9% of electricity in the UK

Pumped storage operates to meet peak demand and ancillary services



‘Medium duration’ electricity variability





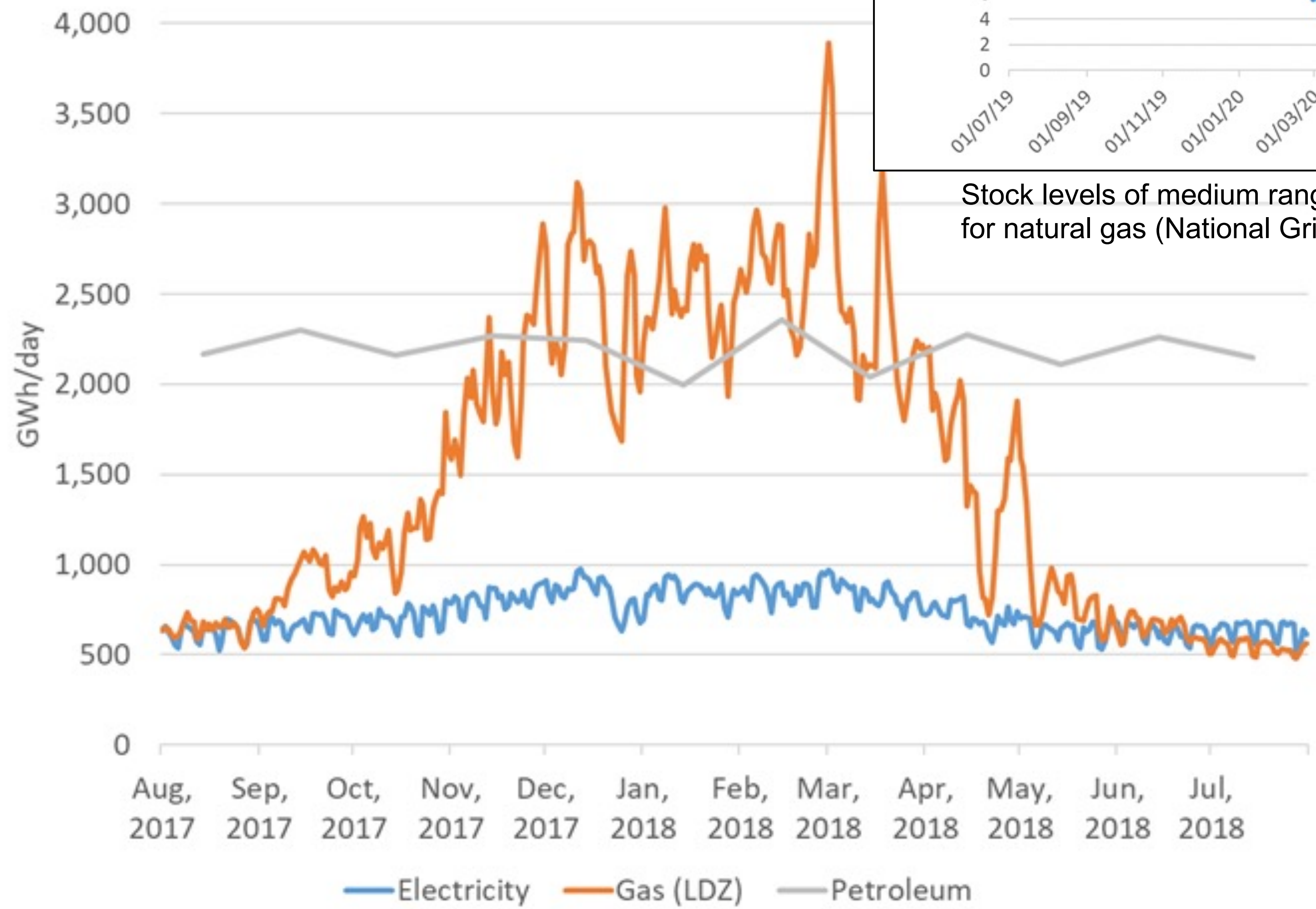
Daily residual load (GWh)

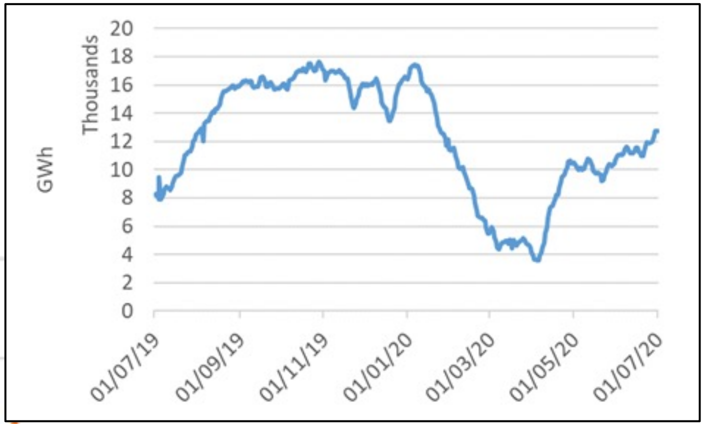
Winter week in 2019, with 2.5x wind and 2x solar (approx NG FES levels for 2030) and no fossil fuel generation.

→ Daily residual load balance ±100s GWh

UoB analysis of data from http://gridwatch.templar.co.uk/ / Elexon / University of Sheffield

Variability in thermal demand



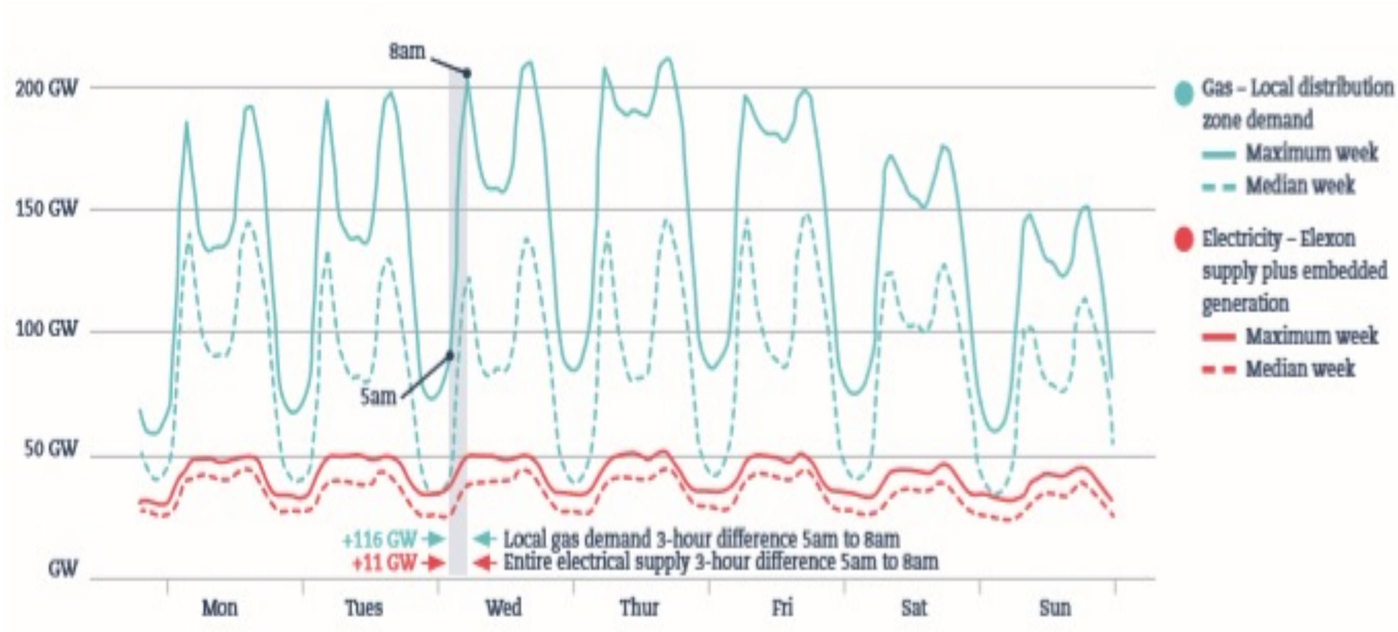


Stock levels of medium range storage for natural gas (National Grid, 2020).

Data sources: gas: National Grid; electricity: National Grid ESO; petroleum: BEIS

Intrinsic storage in the gas network provides peaking capacity for heating.

Hourly demand, peak demand week and median demand week October 2017 - March 2018



Maximum variation over a 3-hour period:

- 16 GW electricity demand
- 116 GW gas demand

Wilson, G., R. Taylor, and P. Rowley, Challenges for the decarbonisation of heat: local gas demand vs electricity supply Winter 2017/2018. 2018, UK Energy Research Centre: London.

Energy storage technologies are emerging as a way of providing flexibility and resilience

Broad family of technologies, with different characteristics:

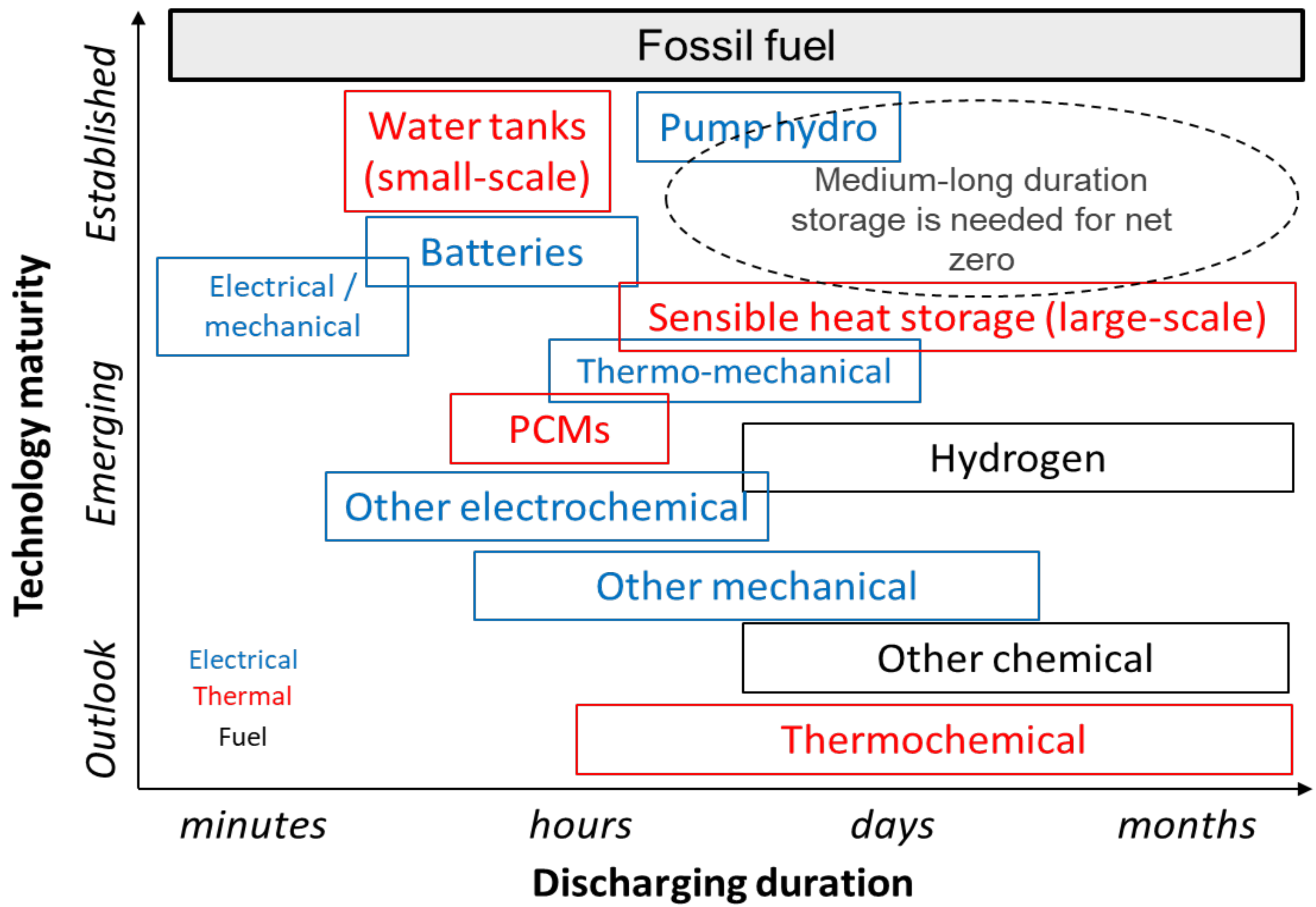
- mechanical (e.g. pumped-hydro, flywheels)
- thermo-mechanical (e.g. liquid air, compressed air, pumped thermal)
- electrical (e.g. capacitors)
- electrochemical (e.g. lithium-ion batteries)
- thermal (e.g. hot water tanks, molten salt)
- chemical (e.g. fossil fuels, hydrogen)

Can be integrated across the energy system:

- Network connected: transmission/distribution levels
- Demand-side: 'behind-the-meter' batteries, in EVs, building-integrated
- Supply side: pre/post-conversion (e.g. generation integrated, GIES)

→ Consider the energy service demand.

Services								
Ancillary services	Reserve	Intra-day peak shifting	Inter-day levelling	Seasonal electrical peak shifting	Seasonal thermal peak shifting	Black Start	Network Upgrade Deferral	UPS



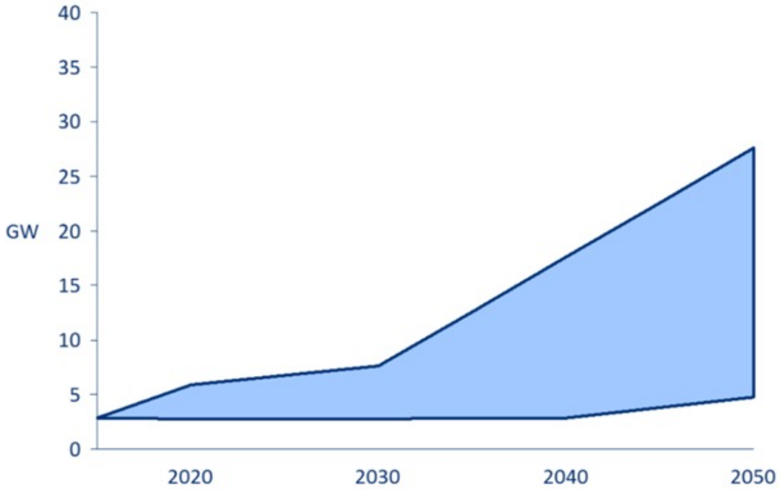
Source: University of Birmingham analysis

Scenarios for storage

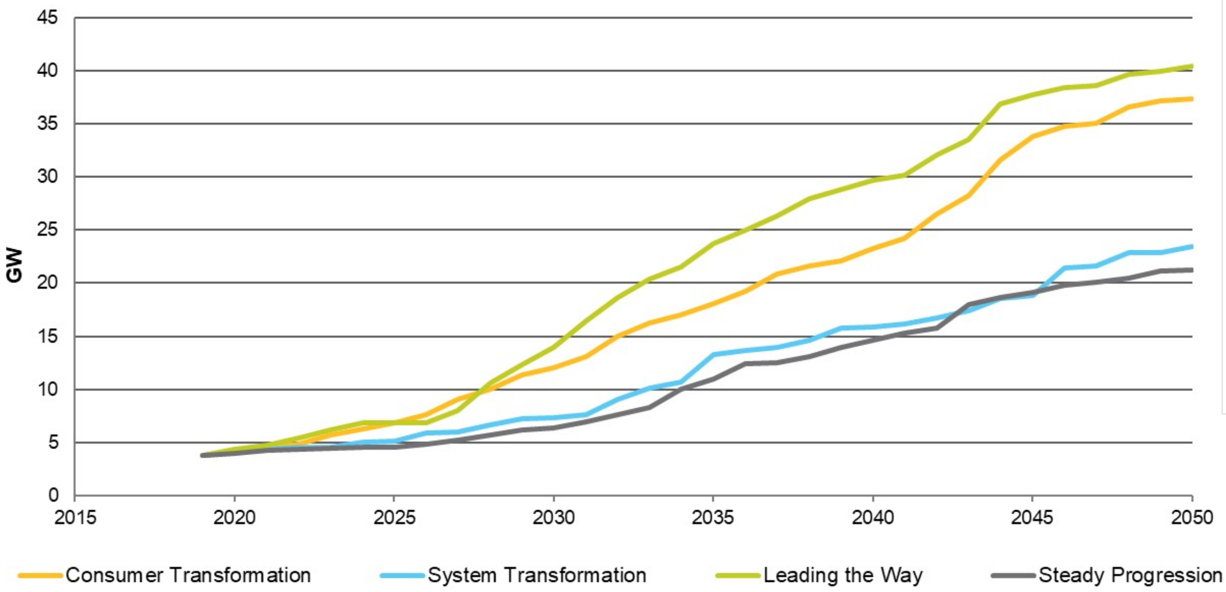
Uncertainties in technology cost projections, of storage and alternatives.

Challenge of modelling at sufficient time and geographic scales, and assessing whole-system value.

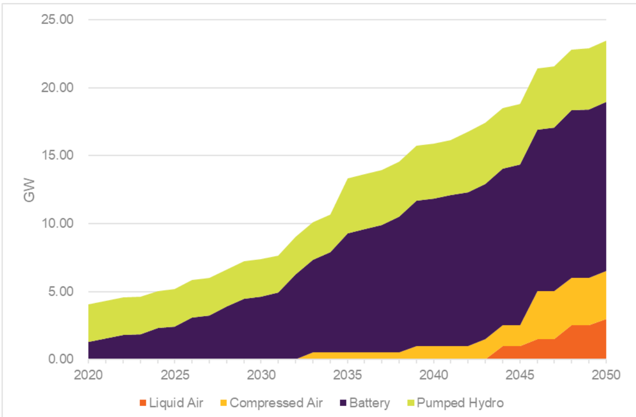
→ Wide range of potential deployment, but possble increases 3 – 10x current scale



Range of optimal deployment of energy storage to 2050 across twelve core scenarios considered by Carbon Trust & Imperial College, 2016.



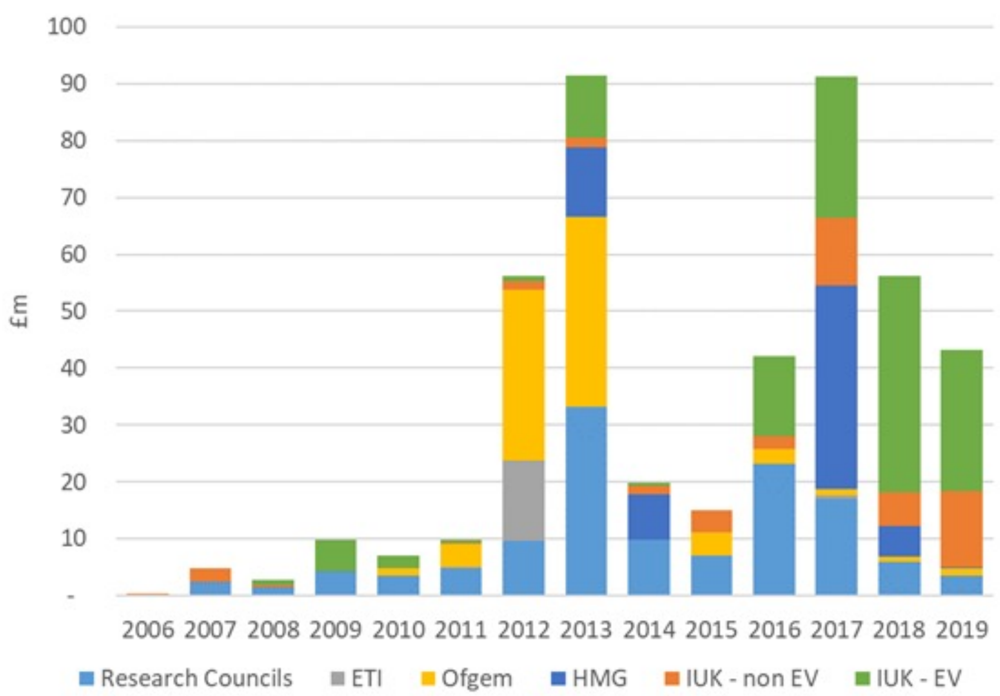
National Grid FES 2020
Installed electricity storage capacity



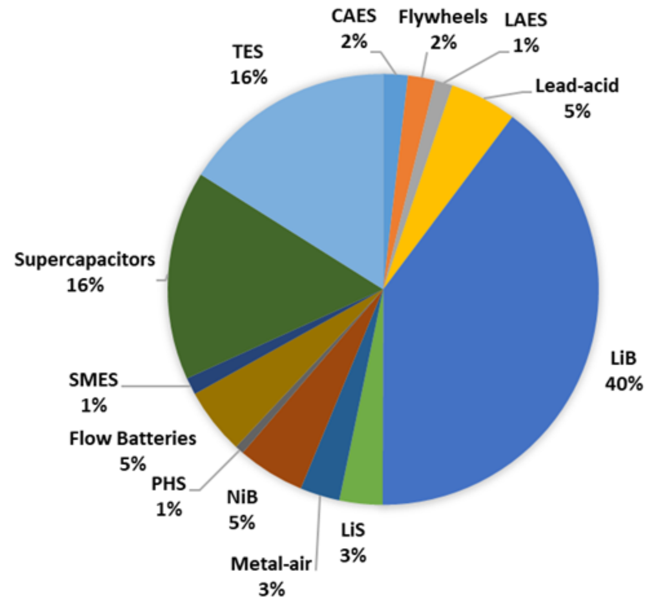
System transformation scenario: energy storage technologies

Research & innovation landscape

- RD&D critical to reducing costs and improving performance of technologies; and energy systems analysis
- Most funding and publications in the field of batteries…



Funding by award date (not including £111m UKBIC, £75m Faraday Institution)



Energy storage articles 2000 - 2020 by technology from the UK

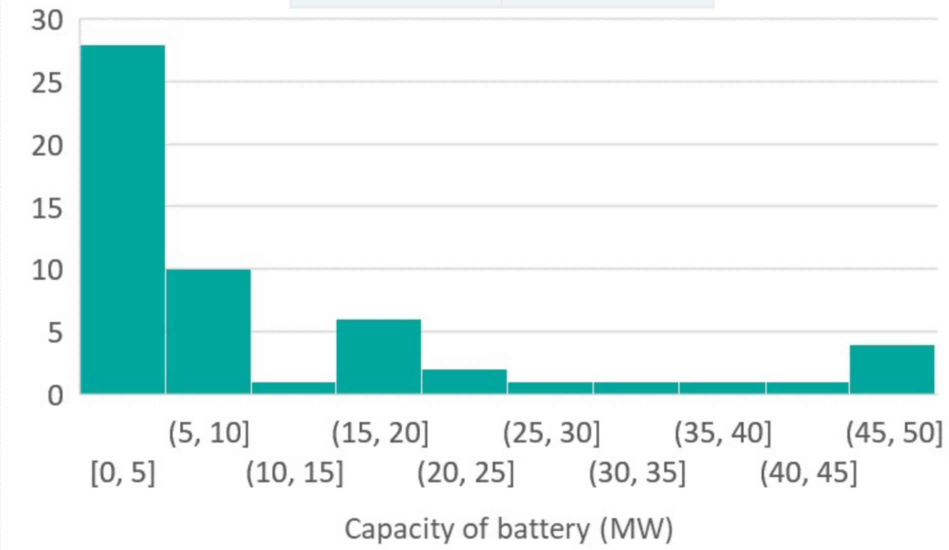
Data sources: UKRI: GtR database; Ofgem: ENA smarter networks portal; HMG: BEIS/DECC innovation funding; articles: Web of Science

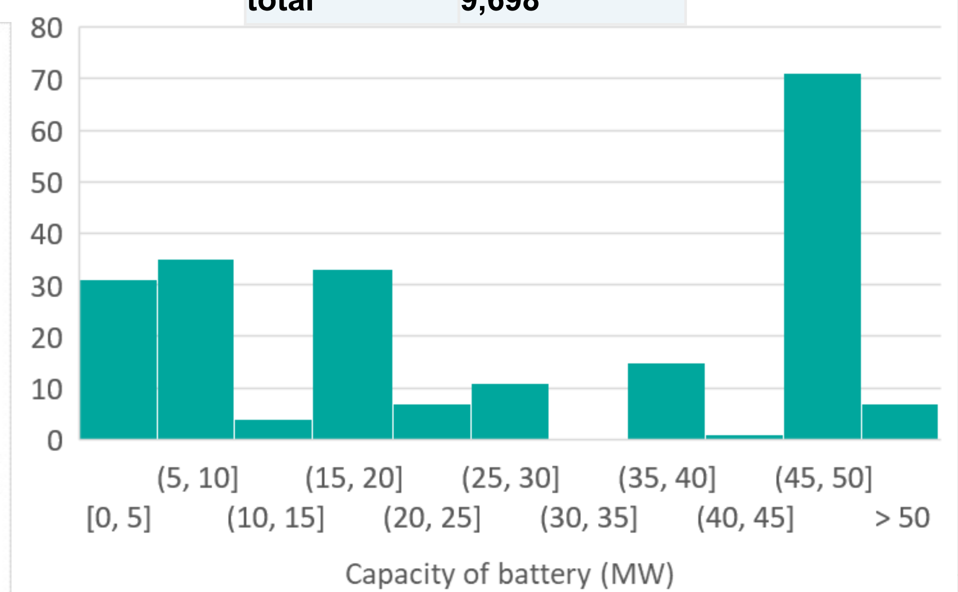
Storage needs market value for deployment

- Batteries have benefitted from markets to provide capacity and frequency response, with costs driven down by auto sector deployment.
- No 'market pull' for medium – long duration: arbitrage value too low to incentivise.

Operational energy storage (September 2020)	
PHS	2,828
LAES	5
battery	632
total	3,465

'Planned' energy storage	
PHS	2,909
battery	6,789
total	**9,698**

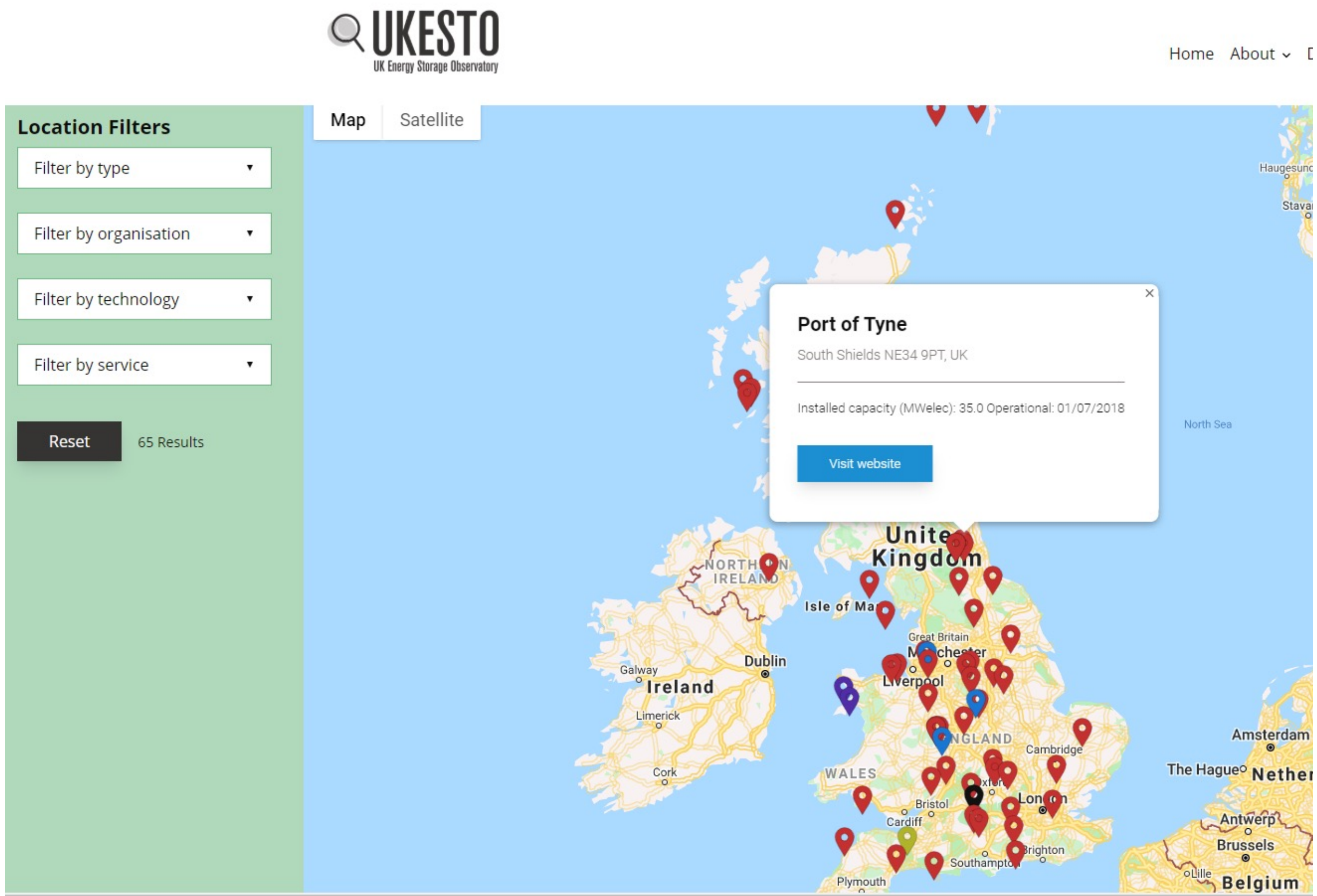




Source: Renewable Energy Planning Database (BEIS)

UK Energy Storage Observatory

https://ukesto.supergenstorage.org/



Funded by EPSRC through MANIFEST project, EP/N032888/1
https://gtr.ukri.org/projects?ref=EP%2FN032888%2F1

Roadmap

Current status:

Energy system

- Growth in variable RES → increasing need for ancillary services

Energy storage potential

- Need for quick response/reserve
- Batteries commercial in some auto sector niches and grid markets

R&I priorities:

<u>Continue</u>

- Strengthen electrochemical battery RD&D base [Faraday]
- Assess degradation effects

Early 2020s:

Energy system

- High proportion of RES, fossil fuel reducing, increasing local generation
- Growing take-up of EVs

Energy storage potential

- Medium – large scale inter/intra-day peak shifting/load levelling to maximise utilisation of networks & capacity; across scales, potentially aggregated
- EV batteries aggregated through V2G

R&I priorities:

<u>Continue</u>

- Electricity market and regulatory reforms to value energy storage services

<u>Act now</u>

- RD&D across potential larger energy scale energy storage technologies
- Investment in EV manufacturing skills/plant
- Technical and policy/regulatory integration of auto/electricity systems
  - Systems analysis for EV charging configurations; V2G
  - Potential for novel business models
  - Analysis of local scale/distributed contributions
- Environmental/resource impacts of ESTs

Mid - late 2020s

Energy system

- Decarbonisation of heat starting, but no clear technological pathway
- Uncertain nuclear capacity, possible flexibility emerging from CCS
- Wider transport decarbonisation

Energy storage potential

- Integration with heat demand; seasonal thermal peak shifting
- Battery second-life (& recycling challenges); HGVs

R&I priorities:

Continue

- Environmental impacts of energy storage technologies

Act now

- Develop/test/demo technologies with seasonal timescales
- Circular economy approaches to EV manufacturing
- Systems analysis including heat

Prepare soon

- Technical & policy/regulatory integration of auto/heat/elec systems
- Establish institutional competencies across scales

Conclusions

- Energy storage is not the only option to provide reliability and resilience, but is credible; without alternatives, fossil fuel may remain locked-in.
- Energy storage provision needs to increase significantly across scales and vectors.

- Re-balance energy storage research and innovation funding according to system-need w.r.t. net-zero, but not diminish the opportunity for batteries.
- Large-scale piloting and demonstration of medium – long duration ES.
- Develop common analytical and modelling frameworks.

- Policy and regulation should (as ever) consider whole-system aspects:
  - Integration of power, heat and transport
  - Impacts of (massively) distributed energy storage
  - Environmental and social impacts of new technologies
- Needs market pull mechanisms to reflect the system value of storage.
- UK well-placed with academic and business expertise.

Thank you

to colleagues in Energy Systems and Policy Analysis group:

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EPSRC

Supergen Storage Network Plus EP/S032622/1 https://supergenstorage.org/

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