



# Energy Storage Presentation



# Why Electricity Storage is Increasingly Important

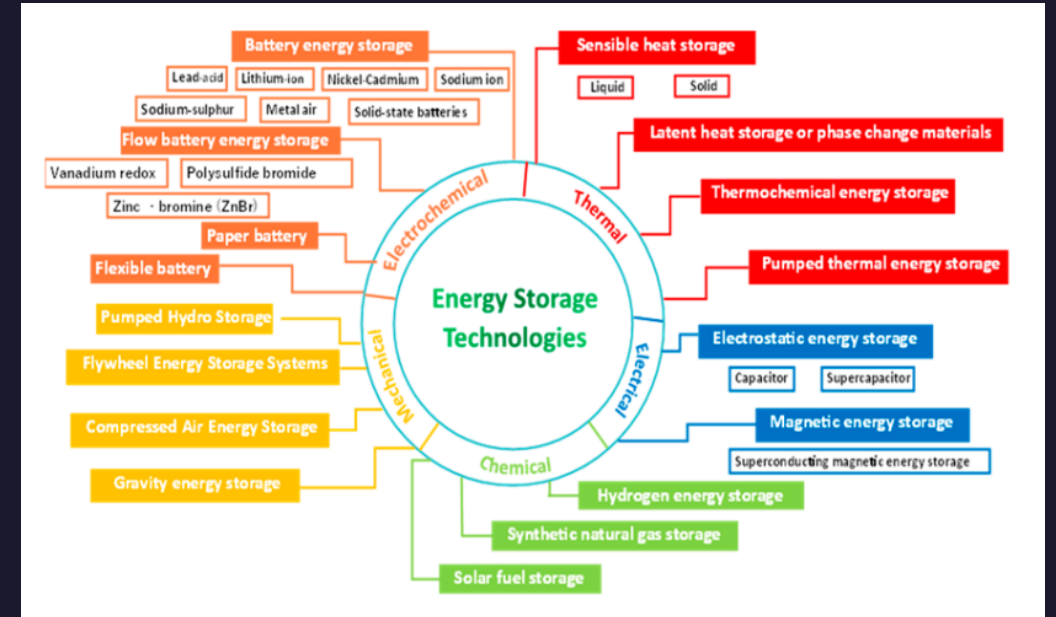
Renewable energy sources are on the rise in the UK, currently providing over half of total electricity generation and set to fill the other half by 2050, in line with the net zero target (National Grid, 2024; Renewable UK, 2019).

Unlike conventional sources, many renewables generate electricity intermittently, relying on energy storage technology to be effectively harnessed (Santecchia et al, 2023). In the UK, this bracket includes some of the biggest providers such as wind and solar (nearly 70% of renewables according to Renewable UK) (Poynting, Yale and Carr, 2026; Renewable UK, 2019).

The UK's history of energy production has resulted in a grid system which doesn't have the flexibility to cope with sporadic energy production (National Grid, 2025). By its nature, it's designed to meet demand through steady generation - overcoming this means creating mass capacity for energy storage (Edwards and Dobson, 2025).

# What Technologies Exist

Batteries are the most obvious and widely used storage technology, although several types exist, each with their own benefits and drawbacks (Viswanathan et al, 2022). When assessing storage methods, there are several considerations which affect their potential for commercial adoption (Rahman, Kim and Hossain, 2022). These include cost (which can be broken down into capital, operating and decommissioning costs), efficiency, lifespan and efficacy (Viswanathan et al, 2022). Aside from economic factors, environmental and ethical considerations also arise (concerning batteries particularly) (Thomson, 2025; Huang and Li, 2022).



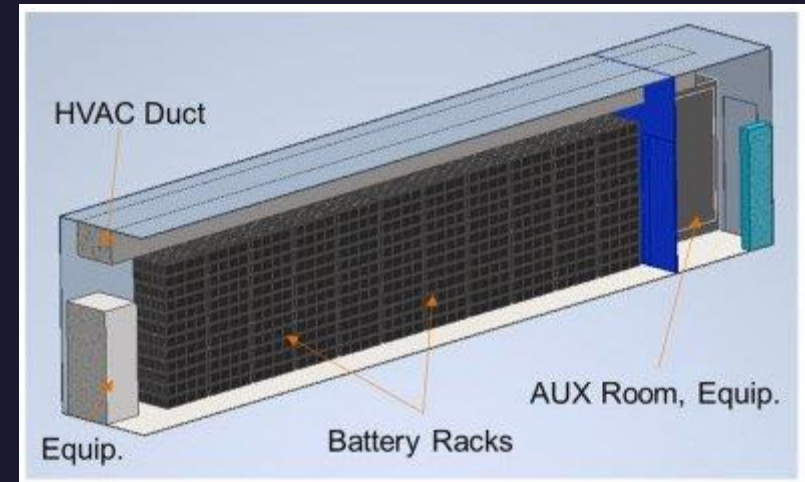
[Figure 1: Energy Storage Categories (Badea et al, 2024)]

# Battery Energy Storage Systems (BESS)

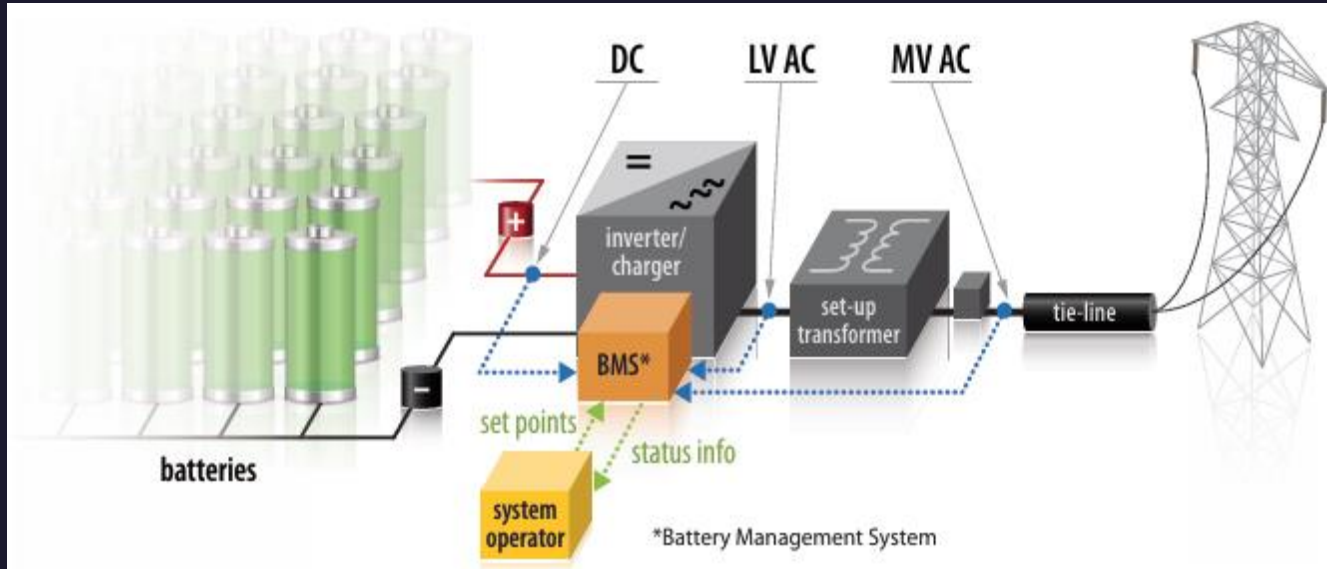
Electricity storage in the UK is becoming increasingly in demand as renewables grow, with BESS acting as the backbone technology (444 GWh in the pipeline) (Edwards and Dobson, 2025; Murray, 2025).

Traditionally used in ancillary roles, their ability to integrate into the grid and cope with variable input and output makes them central to the future of renewable energy (Prakash et al, 2022).

Whilst BESS provide a vital role, cost, lifespan and safety are all currently concerns for use long-term (Rana et al, 2022).



[Figure 2: Typical BESS system (Cozen et al, 2023)]



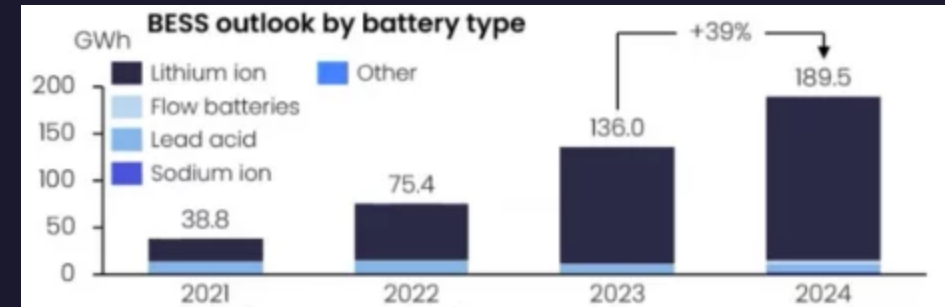
[Figure 3: BESS integration with the national grid (Bowen, Chernyakhovskiy and Denholm, 2019)]



[Figure 4: Planned BESS site at Herne Bay, Salford (Face, 2026)]

# Lithium-ion Batteries

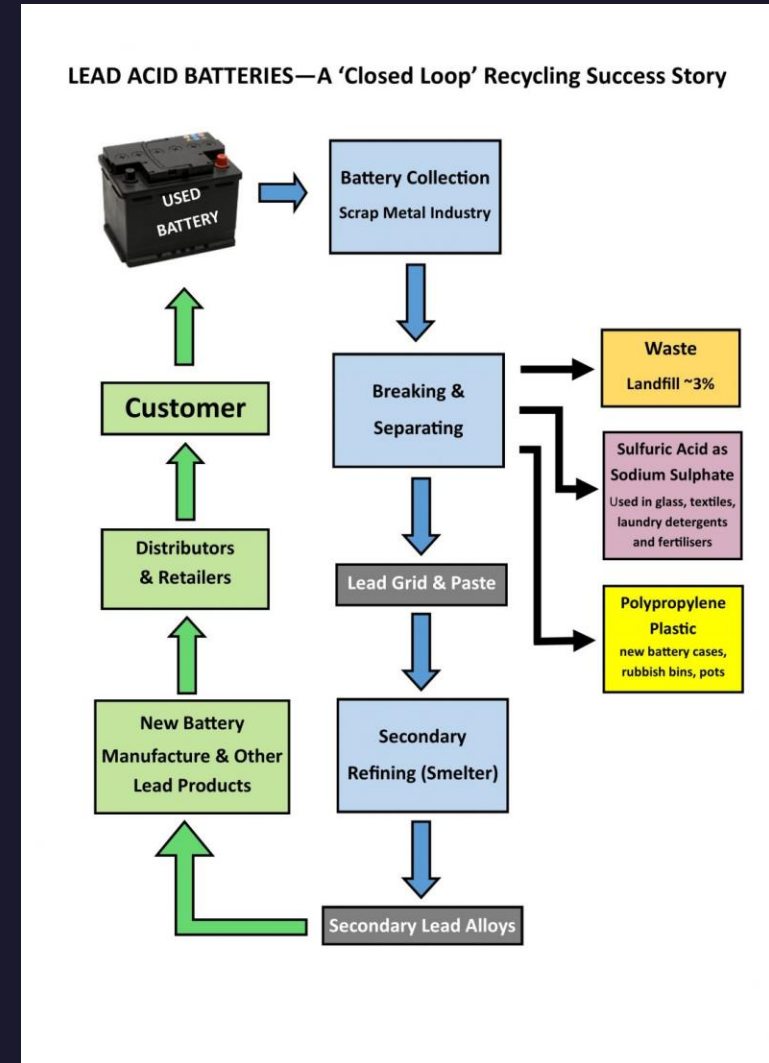
Lithium-ion batteries are by far the most common type of battery used BESS in the UK due to their high energy density, cost effectiveness and cycling performance (Conzen et al, 2023; Edwards and Dobson, 2025; Viswanathan et al, 2022). Their chemical components also make them liable to fire / explosion hazards, particularly when used in high density (such as in BESS) (Conzen et al, 2023).



[Figure 5: Lithium-ion battery use in BESS (Best Magazine, 2023)]

# Lead-Acid Batteries

Lead-acid batteries, whilst an older technology, still have a foothold, particularly in auxiliary / back up BESS systems (May, Davidson and Monahov, 2018). Despite their reputation for being outdated, many improvements to the technology have been made, making them suitable for many modern applications (May, Davidson and Monahov, 2018). Lead-acid exhibits some advantages over lithium ion, especially in capital cost and recycling potential, given that lead is the most efficiently recycled commodity metal (May, Davidson and Monahov, 2018; Viswanathan et al, 2022).

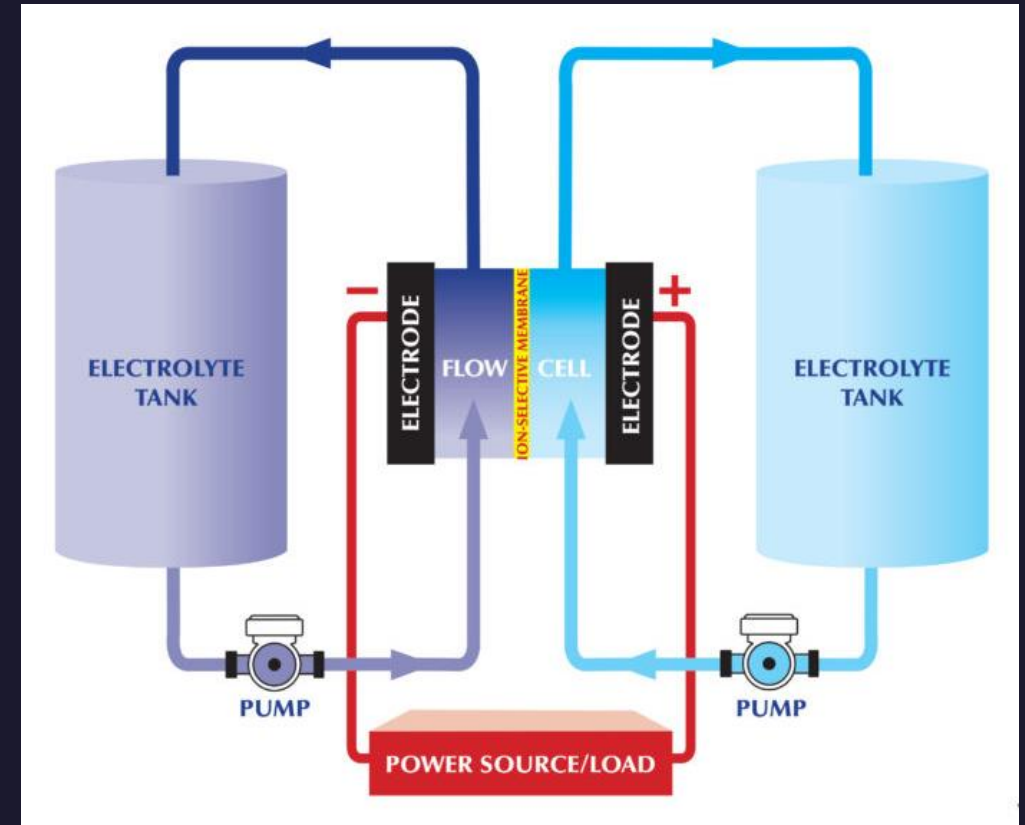


[Figure 6: Lead-acid battery recycling (Battery Rescue, n.d.)]

# Flow Batteries

Flow batteries are distinct from other batteries in that they store their energy in liquid electrolytes (IFBF, 2025). Unique to other variants, they generally excel in safety, overall lifespan and operation time (IFBF, 2025). Whilst typically more expensive than lithium-ion, these attributes make them key candidates for coping with fluctuations in grid supply (IFBF, 2025).

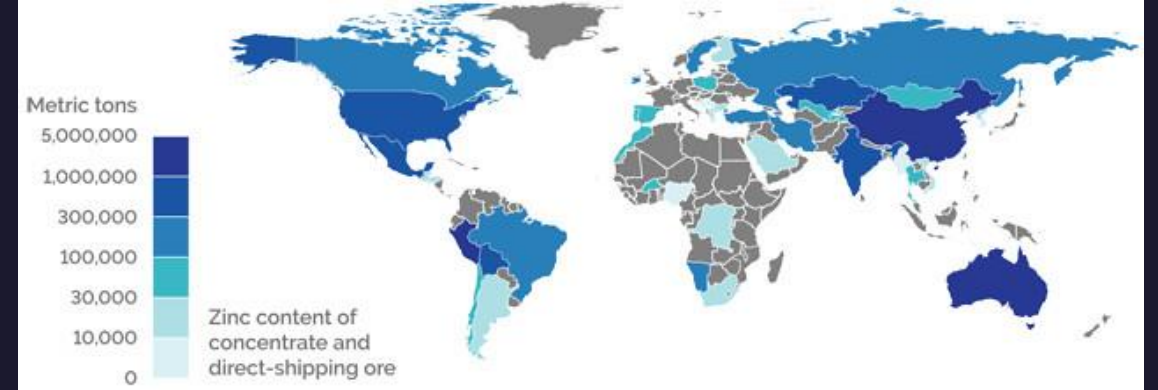
Vanadium redox are the most widespread variants of flow batteries, with a track record of commercial success in both charging stations and grid stabilisation (Viswanathan et al, 2022).



[Figure 7: Flow battery diagram (IFBF, 2025)]

# Zinc-Based Batteries

When broken down, zinc-based batteries either come under the category of zinc-air (non-rechargeable), or zinc-ion (Viswanathan et al,2022). For incorporation into the grid, zinc-ion are an attractive alternative to lithium, being cheaper, longer-lasting and safer (Battery Factory, 2025; Viswanathan et al, 2022). Another valuable attribute of zinc-based batteries (particularly in light of growing demand) is their sustainability, given that zinc is a relatively abundant metal (Viswanathan et al,2022).



[Figure 8: Zinc abundance across the globe (Earth Magazine, 2015)]

# Sodium Nickel Chloride (ZEBRA) Batteries

In a similar vein to zinc-based batteries, zebra batteries are known for their safety and recyclability; both useful characteristics for mass use (Prakash et al, 2022). Again, like zinc-based batteries, they are composed of commonly found resources, providing a much sought after alternative for the lithium dominated market (Heinz et al, 2025; Prakash et al, 2022).

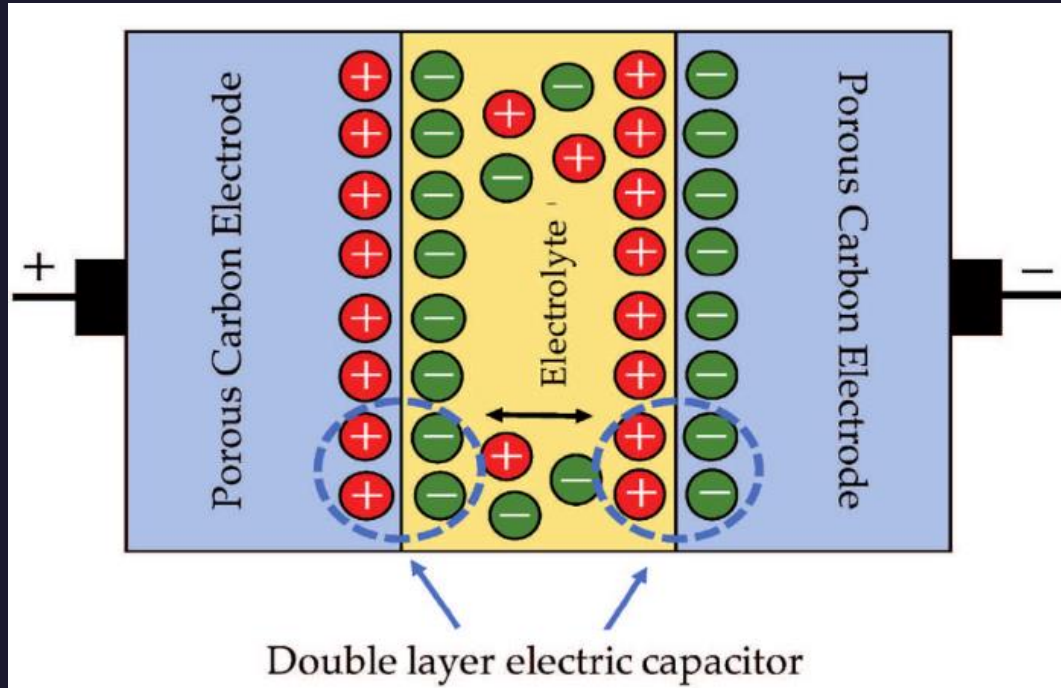
| Type                   | Benefits                                                                                                                                                                                                                                                                | Drawbacks                                                                                                                                                                                         |
|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Li-ion                 | High DoD<br>High power<br>High energy density<br>Low discharge rate<br>Stable discharge voltage<br>High cell voltages<br>High cycle efficiency<br>Wide operating temperature<br>Good performance<br>Packing flexibility<br>Recyclable lithium oxides<br>Long life cycle | Environmental and safety issues<br>Require protection technology<br>High cost associated with it<br>Temperature dependent<br>Poor recovery and recycling<br>Need advance energy management system |
| Lead acid              | Well developed technology<br>Good storage capacity<br>Low self-discharge rate<br>Good packing - spill proof<br>Fast response time<br>Low investment cost compared to Li-ion                                                                                             | Environmental and safety issues<br>Low DoD<br>Low cycling capability<br>Increased costs at low temperature<br>Bulky<br>Low specific energy and energy density                                     |
| Sodium Nickel Chloride | High energy density<br>Long life cycle<br>Long discharge time<br>Fast response<br>Low investment cost compared to Li-ion                                                                                                                                                | High operation and maintenance cost<br>High self-discharge<br>Requires heat for molten state temperature                                                                                          |

[Table 1: Benefits and drawbacks in relation to other common battery types (Prakash et al, 2022)]

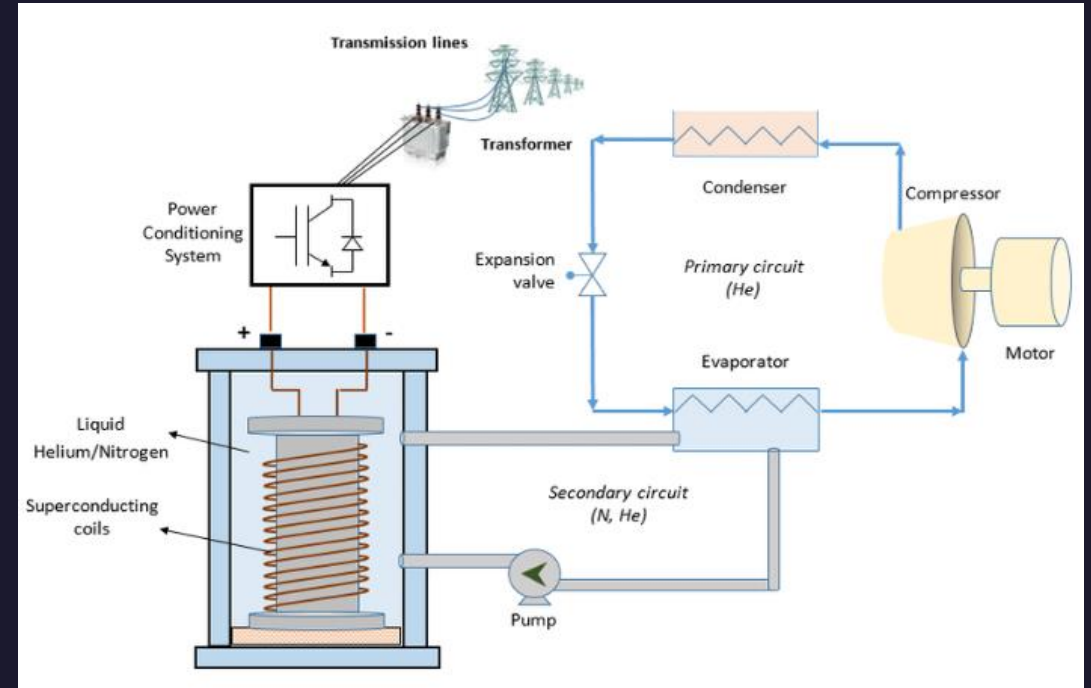
# Additional Electrical Energy Storage Technology

Supercapacitors are technologies that store energy electrostatically rather than chemically, bridging the gap between batteries and capacitors (Nayak, Joshi and Nayak, 2024). In BESS, they are used to compliment batteries, providing voltage regulation which increases optimal performance and potential lifespan (Nayak, Joshi and Nayak, 2024).

Superconducting magnetic energy storage (SMES) is a pioneering technology which harnesses magnetic fields, using superconducting coils (Energy Bases, 2024). SMES is highly efficient and boasts incredibly fast response times (milliseconds) but suffers from high capital costs and requires cryogenic cooling (Energy Bases, 2024). Ultimately because there are no moving parts, cycling capability is theoretically unlimited (Energy Bases, 2024). Whilst a revolutionary technology, it's uptake so far has been slow due to cost and practicality (Energy Bases, 2024).



[Figure 9: Supercapacitor structural diagram (Mayoral et al, 2021)]



[Figure 10: SMES technology implemented into grid infrastructure (Nikolaidis, 2019)]

# Mechanical Energy Storage

**Pumped Hydroelectric (PHES):** Uses similar principals to SGES, harnessing gravitational potential energy using weight (water), pumped to a higher elevation in a reservoir (Hammad et al, 2024). Despite being highly cost-effective, this method relies on specific topography (Hammad et al, 2024; U.S. Department of Energy, 2024).

**Compressed Air (CAES):** Stores air in compressed tanks to be released during times of high demand and converted back to electricity (Rabi, Radulovic and Buick, 2023). CAES systems work by heating and expanding the air in a turbine, reverting back to its original pressure (Rabi, Radulovic and Buick, 2023).

**Gravity (SGES):** A highly economical and sustainable load balancing technology, converting energy between gravitational potential and electricity (Tong et al, 2022). Within the grid, excess electricity is stored by lifting weights which can be released to generate electrical power (Tong et al, 2022).

**Flywheel (FESS):** Energy is stored in kinetic form and can be either charged, discharged or held (Xu et al, 2023). These systems offer great potential for long term savings due to their efficiency and durability (Xu et al, 2023).

# Thermal Energy Storage

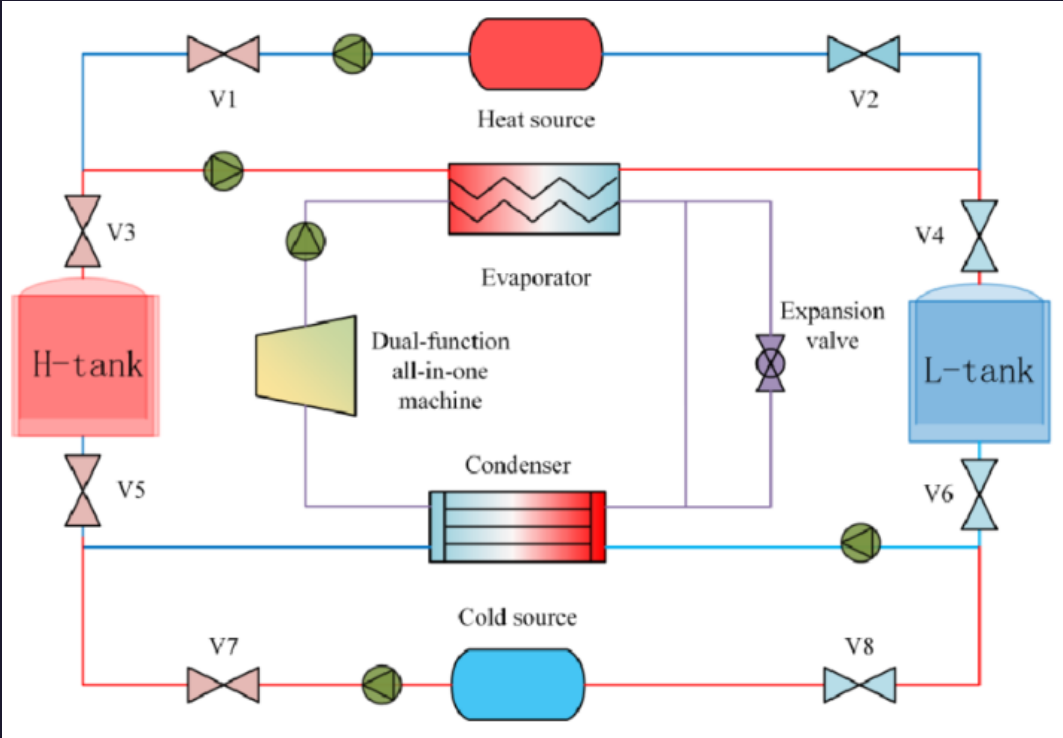
**Thermal:** Within thermal energy storage, there are several sub-categories, with sensible heat storage being the most commonly used (Irena, 2020; Kumari, 2025). In this technology, heat be sourced directly from renewables such as solar and stored in various mediums (generally water or rock), without changing its state (Irena, 2020; Kumari, 2025). Thermal storage is considered a highly flexible for long-term energy storage, where batteries generally suffer (Kumari, 2025).

**Carnot Batteries:** Whilst called batteries, these technologies are hybrid systems which convert electricity into thermal energy for storage, and then back into electricity for discharge (Novotny et al, 2022). Despite being an emerging technology, their potential to be a cost-effective solution in long term energy storage (a sector in demand), is strongly anticipated (Novotny et al,2022).



| Storage type   | Segment                                                                           | Efficiency (%) | Range          | Storage period  | Cost (EUR/kWh) | Technology                                                                                                                                                                         | TRL         |
|----------------|-----------------------------------------------------------------------------------|----------------|----------------|-----------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| Sensible       |  | 50-90          | <0°C to 100°C  | Hours to months | 0.1-30         | <ul style="list-style-type: none"> <li>Water tank TES</li> <li>Underground TES</li> <li>Solid-state thermal storage (e.g. ceramic bricks, rocks, concrete, packed beds)</li> </ul> | Medium-high |
| Latent         |  | 75-90          | <0°C to >100°C | Hours           | 50-200         | <ul style="list-style-type: none"> <li>Ice thermal storage</li> <li>Sub-zero temperature</li> <li>Phase-change materials (PCMs), low-temperature PCMs</li> </ul>                   | Medium-high |
| Thermochemical |  | 50-65          | 0°C to 100°C   | Hours to month  | 15-130         | <ul style="list-style-type: none"> <li>Sorption, salt hydration, absorption and adsorption systems</li> </ul>                                                                      | Medium      |

[Table 2: Comparison of different thermal storage technologies (Irena, 2020)]

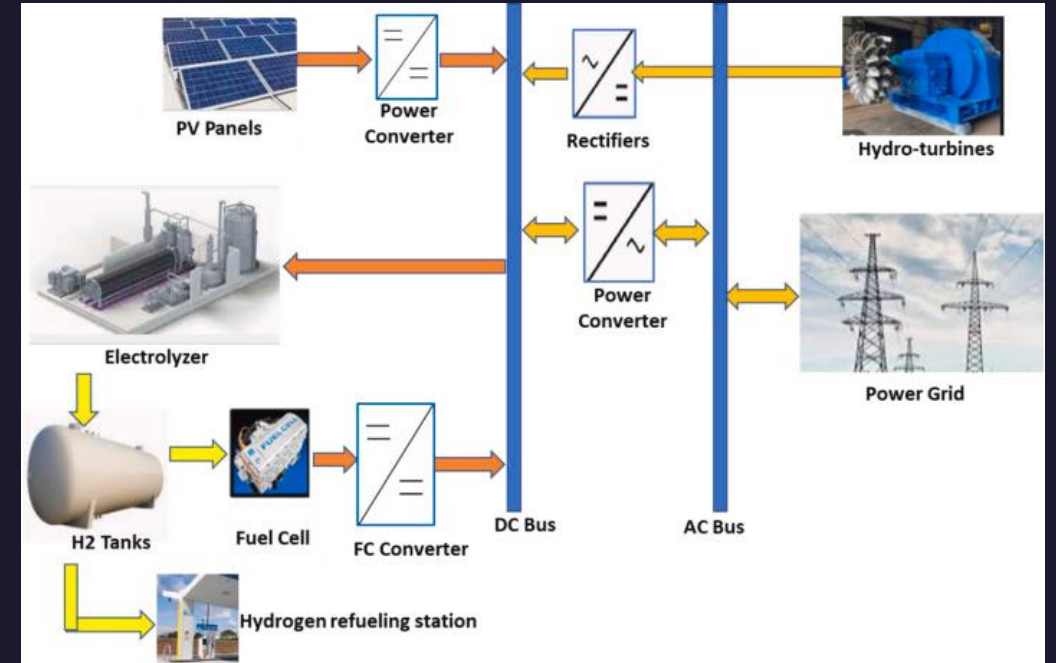


[Figure 11: Carnot battery diagram (Ma and Yang, 2023)]

# Hydrogen Fuel Cells

Whilst many synthetic fuels exist, hydrogen is unique in that it only emits water vapour when combusted (Kimpton et al, 2023). This makes it an ideal buffer technology for renewable energy storage, with long-term application in grid settings (Kimpton et al, 2023).

Whilst minor compared to carbon dioxide or methane, water vapour, is a GHG itself, meaning hydrogen isn't 'green' by definition (Ocko and Hamburg, 2022). Additionally, current hydrogen production is largely powered by fossil fuels, further detracting from its potential as a carbon neutral storage technology (Kimpton et al, 2023; Ocko and Hamburg, 2022).



[Figure 12: Hydrogen integration into the grid (Zghaibeh et al, 2024)]

# Global Picture

Whilst the UK has made radical changes to its energy storage, there is still wide scope to learn from other parts of the world. In Europe, Belgium has given the world the first industrial-scale ammonia cracking plant, which has been developed to produce carbon neutral hydrogen (Air Liquide, 2025). This has created the potential for green hydrogen to rapidly grow and marks a step in the advance of renewable fuels / storage technologies (Air Liquide, 2025).

In Asia, China has been instrumental in many fronts of storage technology, although the development of solid-state batteries (expected to come into fruition in 2027), is arguably the most significant (Yuan Trends, 2025). Moving south, India's clean energy agenda has produced a 500-gigawatt target for 2030, supported largely by investment in storage technologies (Kumari, 2025).



# Uptake / Future Outlook in the UK

Future honing of BESS technology, including a multitude of upcoming batteries (solid state, aluminum-ion, iron air etc.), offers space for the UK to further develop its renewables (UK Battery Strategy, 2023). These developments will expand the parameters of batteries, providing greater energy density, lifespan and faster charging times (as well as other benefits) (UK Battery Strategy, 2023). Ultimately this will allow the UK to meet its target of 100% renewable electricity for 2030, stated in its clean power action plan (UK Government, 2024).

Whilst the UK has vastly expanded BESS, other sectors have seen little growth (Prakash et al, 2022).

Development of multiple storage technologies (mechanical, thermal and chemical), should be implemented as part of a diversified energy storage portfolio, which reduces reliance on any individual sector and creates greater flexibility in the grid.

Finally, whilst energy storage is a largely undisputed component of the net zero goal, Barrett et al (2021), argues that, in order to avoid huge expense, attention should be targeted at reducing energy demand, encouraging a wholistic, efficiency-based approach.

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