INTESA SANPAOLO
INNOVATION CENTER

NEST
NETWORK FOR ENERGY SUSTAINABLE TRANSITION

INDUSTRY TRENDS REPORT

ENERGY, ENVIRONMENT & UTILITIES

ENERGY STORAGE

FROST & SULLIVAN

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EXECUTIVE SUMMARY

With the increasing integration of variable and intermittent renewable energy sources, electricity transmission & distribution grids face a range of challenges. These could, at least partially, be addressed by the development of robust and reliable ***battery*** (BES) and ***non-battery*** (NBES) **energy storage** solutions.

The latter group covers ***mechanical, electrical, chemical*** and ***thermal*** approaches whilst the former area notably includes ***electrochemical*** technologies. Within this, there is variation in terms of cost, reaction time and lifespan and also function, capacity and efficiency.

Overall, the non-BES segment currently represents 86% of the total market with Frost & Sullivan forecasting investment of $178.5 billion (b) globally between 2022-2030. Growth is driven by its advantages, such as its capacity to store for long durations, as well as the disadvantages of BES, like its reliance on rare earth metals.

Pumped hydro storage (PHS) dominates the total market and the non-BES segment due to its application in brown and greenfield contexts. The technology converts electrical into gravitational energy in water and favours energy arbitrage with installed capacity expected to reach 1,576 gigawatts (GWs) by 2030. Quidnet (United States, US) has developed a cost effective geo-mechanical PHS proposition.

Indeed, pumped hydrogen storage forms part of <u>mechanical</u> category with the other key approaches including ***gravity***, ***compressed*** and ***motion*** solutions. ***Gravitational*** storage uses solid mass instead of water, largely for peak shaving; ***compressed*** storage deposits energy in underground caverns at high pressure and is intended primarily for load shifting and ***motion*** storage captures grid energy in a flywheel, mainly for voltage control.

North America and Europe lead the way in terms of the provision of mechanical energy storage funding and other initiatives with Gravity Power (US), Energy Dome (Italy) and Beacon Power (US) notable innovators in gravitational, compressed and motion areas.

In the <u>electrical</u> category, ***capacitors*** offer a round trip efficiency of up to 99% so provide a complement to primary energy sources by releasing power when needed.

Their highest penetration is in countries with strong wind energy potential where they fulfil a role in capacity firming with new ultracapacitors benefiting from advances in the availability and sustainability of their composite materials.

Researchers at the Washington University (US) are exploring the use of a novel 2D/3D/4D heterostructure that minimises energy losses while Skeleton Technologies (Germany) is a leading developer of supercapacitors with its innovation delivering 10x the density of conventional technologies. UCAP Power (US) has became a major patent holder and ultracapacitor technology leader and is looking capitalize on the potential.

Hydrogen (H2) is the main form of <u>chemical</u> storage and is rapidly emerging as an effective and, more importantly, low- or zero-carbon energy carrier. Green H2 from non-fossil sources has the potential to decarbonise across sectors and leverages large-scale and small-scale storage, notably fuel cells.

The nascent sector is aided by policy initiatives and financial incentives with storage solutions forming the basis of an emerging global hydrogen economy. Storage companies will need to work with partners across the H2 value chain to deploy the 26 GW of projects which are expected to be installed globally by 2030.

SunHydrogen (US), for example, has developed a breakthrough technology to produce hydrogen using only solar energy and any water source while Hydrogenious (Germany) produces innovative liquid organic hydrogen carriers for efficient and effective H2 storage or transportation.

In parallel, ***ammonia*** is emerging as an alternative chemical storage medium since it is as conversion efficient as hydrogen at lower pressures.

The thermal category also has a key role to play in enabling a green energy revolution and benefits from its use of low-cost and locally available storage mediums.

Sensible, latent and ***thermo-chemical*** solutions predominate in this segment and collectively represent a range of technologies with differing characteristics. This translates into a wide application base with thermal energy storage (TES) solutions setting themselves apart and the market expected to grow rapidly with over 600 megawatts under development.

EnergyNest (Norway) provides cost-effective ***sensible*** storage systems which leverage recyclable materials; Azelio (Sweden) similarly uses repurposed aluminium as part of its ***latent*** TES product and SaltX (Sweden) delivers efficient ***thermo-chemical*** storage technology that relies on its nanocoating expertise.

In the future, it is hoped that latent TES solutions in particular will be able to improve the energy efficiency of buildings which today account for 33% of emissions.

In the long run, BES will overtake non-BES to represent 54.5% of total installed energy storage capacity globally by 2030. Here, electromechanical solutions offer numerous benefits including their modularity.

On the ***sealed battery*** side of the market, many new chemistries are under development, but choice remains limited, and lithium-ion dominates. Stationary lithium-ion batteries have benefited from the increased deployment of electric vehicles and the associated recharging infrastructure with, in Europe, demand from the utility sector expected to drive revenues of $3b by 2030, up from just under $745 million in 2022. This will be to the benefit of the market leaders such as Lg Energy Solutions (South Korea), Tesla (US) and Panasonic (Japan) and CATL (China) among others.

Nonetheless, ***flow batteries*** are emerging as a safer alternative to lithium-ion and are better suited to large-scale and long-duration storage. Stationary flow batteries include both true flow and hybrid flow technologies with solutions that use vanadium electrolytes being the most widely available. In Europe, annual capacity additions of vanadium redox batteries (VRFBs) will continue to increase from 100 megawatt hours (MWh) in 2024 to 800 MWh in 2030. VRB Energy, a Canadian company, is the largest non-Chinese manufacturer while offering electrolytes-as-a-service is a model that market participants are exploring to reduce the cost of VRFB systems and boost uptake.

This report examines the innovations and business models across all five main categories of **energy storage** solutions with a focus on exploring the established and emerging technologies and business models which are shaping this dynamic sector.

INTRODUCTION

With the increasing integration of variable and intermittent renewable energy sources, electricity transmission & distribution grids face a range of challenges

The advent of climate change, the announcement of net-zero emission targets and the declining cost of components have collectively spurred the rapid penetration of sustainable energy technologies into the energy mix. According to the International Energy Agency, the total electricity generated from non-biological renewable sources reached 30% globally in 2022. With such a vast share, concerns around grid stability and power quality are increasing at an exponential rate, as is the demand for energy storage technologies.

These could, at least partially, be addressed by the development of robust and reliable *battery* (BES) and *non-battery* (NBES) energy storage solutions

The evolving system and in particular the integration of wind and solar power has created significant energy management issues. These include a mismatch in supply and demand and a drop in frequency or voltage. The principal aim of energy storage solutions is to ensure reliability and provide ancillary services to the grid. By being able to offer long storage durations at low costs, they are especially suited to transmission & distribution grid scale applications and help to make the system both more flexible as well as safe.

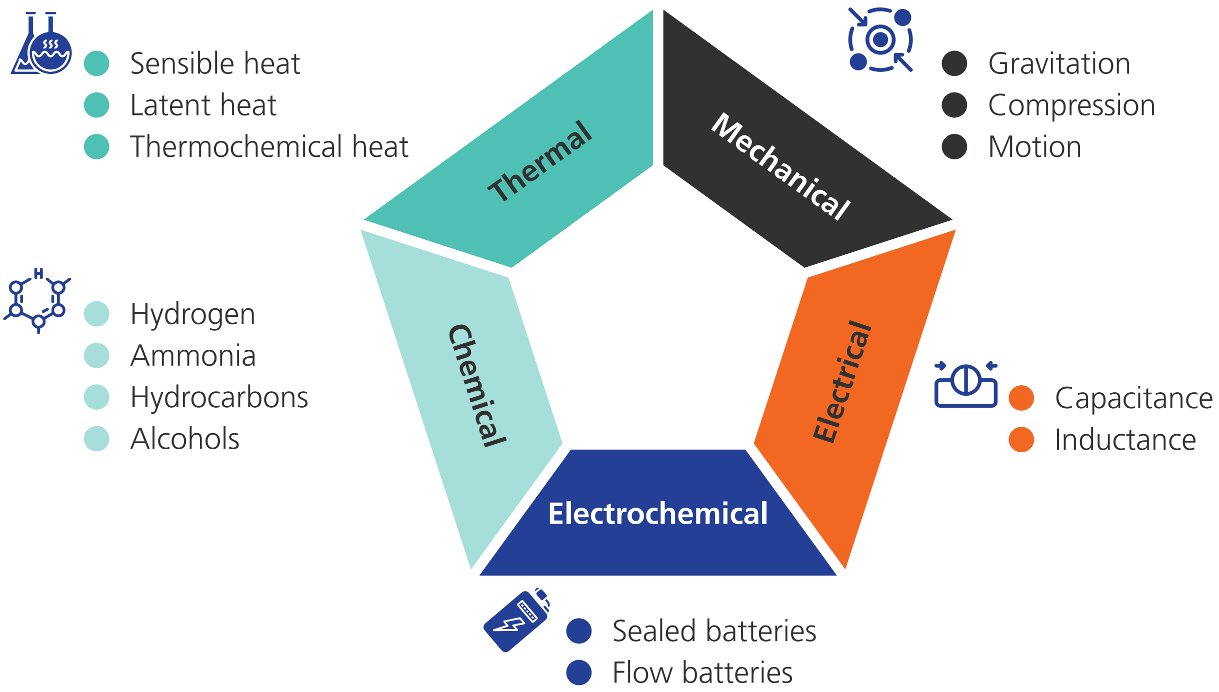
In particular, energy storage solutions are able to support with;

- **frequency regulation** which involves managing power quality via quick responses to changes in voltage and building contingencies for system failures
- **load shifting** which enables the storage of excess electricity when demand is low and the utilization of it later when demand is high. This also reduces curtailment, or a reduction in power production
- **price arbitrage** which includes the purchase of energy generated during off-peak hours at low costs and its sale during peak hours at higher prices
- **peak shaving** which encompasses reducing peak loading for industrial customers which, in turn, lowers their operating costs. For system operators, peak shaving has the benefit of limiting congestion

They also have a role to play in **voltage support**, which involves feeding reactive power to the grid to ensure voltages are in acceptable ranges, and **capacity firming** via the provision of reliable and additional capacity for peak load management.

The latter group covers mechanical, electrical, chemical and thermal approaches whilst the former area notably includes electrochemical technologies

Mechanical includes *gravitational*, *compressed* and *motion* solutions; **electrical** includes *capacitors*; **chemical** includes *hydrogen* and *ammonia*; **thermal** includes *sensible* heat, *latent* heat and *thermo-chemical* heat and **electrochemical** includes *sealed* and *flow* batteries.



Within this, there is variation in terms of cost, reaction time and lifespan ...

The capabilities of selected energy storage technologies include;

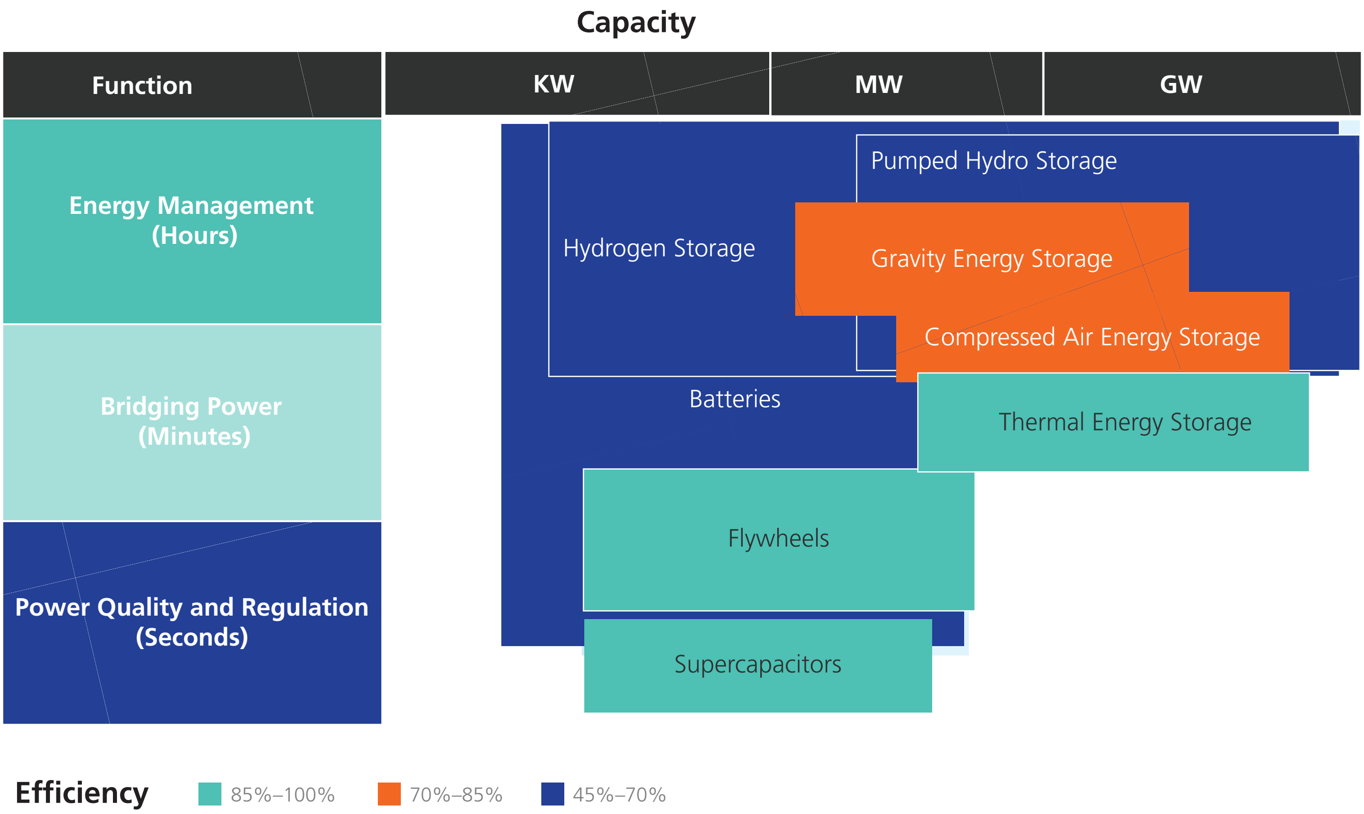
Technology	Cost ($/kWh)	Reaction time	Lifetime
BES: sealed *Lithium-ion*	**352-487**	Sub seconds to seconds	10 years
BES: flow *Flow batteries*	**499-609**	Sub seconds to seconds	15 years
BES: sealed *Lead-acid batteries*	**380-448**	Seconds	12 years
NBES: mechanical *Pumped hydro*	**150-242**	Seconds to minutes	40 years
NBES: thermal *Molten salt*	**20-30 (kWh th)**	Several minutes	30 years

For thermal, 14-hour molten salt energy storage in 100 megawatt (MW) concentrated solar power (CSP) plants has been considered and the costs are defined in terms of thermal kilowatt-hour (kWh th). For lithium-ion, Flow batteries and lead-acid batteries, the cost of storage has been calculated for 10MW 4-hour systems. Similarly, for pumped hydro storage, 1,000MW 10-hour systems have been considered.

Source: Frost & Sullivan

… and also function, capacity and efficiency

Depending on the duration for which they are able to store energy, their capacity – from kilowatts to megawatts to gigawatts (GWs) – and their efficiencies in percentage terms, the function of each technology varies across a range from ***energy management*** (requiring hours) to ***bridging power*** (minutes) to ***power quality*** (seconds).



This report examines the innovations and business models across all five categories, mechanical, electrical, chemical, thermal and electrochemical, with a focus on established and emerging energy storage technologies

Source: Frost & Sullivan

PRINCIPAL **ABBREVIATIONS**

B	*Billion*	**LOHC**	*Liquid organic hydrogen carrier*
BES	*Battery energy storage*	**MES**	*Mechanical energy storage*
C	*Celsius*	**MW**	*Megawatt*
CAES	*Compressed air energy storage*	**MWh**	*Megawatt hour*
CAPEX	*Capital expenditure*	**MWh**	*Megawatt-hour*
CO2	*Carbon dioxide*	**NBES**	*Non battery energy storage*
CSP	*Concentrated solar power*	**PCM**	*Phase-changing materials*
FES	*Flywheel energy storage*	**PHS**	*Pumped hydro storage*
Ft	*Feet*	**R&D**	*Research & Development*
GES	*Gravity energy storage*	**RFB**	*Redox flow battery*
GHG	*Greenhouse gas*	**RTE**	*Round-trip efficiency*
GW	*Gigawatt*	**TES**	*Thermal energy storage*
H2	*Hydrogen*	**UK**	*United Kingdom*
kWh	*Kilowatt-hour*	**US**	*United States*
LAES	*Liquid air energy storage*	**V2O5**	*Vanadium pentoxide*
LCOS	*Levelized cost of storage*	**VRFB**	*Vanadium redox battery*
LDES	*Long duration energy storage*	**W/l**	*Watts per litre*
Li-ion	*Lithium-ion*	**Wh/l**	*Watts-hours per litre*

Source: Frost & Sullivan

ABOUT INTESA SANPAOLO INNOVATION CENTER:

Intesa Sanpaolo Innovation Center is the company of Intesa Sanpaolo Group dedicated to innovation: it explores and learns new business and research models and acts as a stimulus and engine for the new economy in Italy. The company invests in applied research projects and high potential start-ups, to foster the competitiveness of the Group and its customers and accelerate the development of the circular economy in Italy.

Based in the Turin skyscraper designed by Renzo Piano, with its national and international network of hubs and laboratories, the Innovation Center is an enabler of relations with other stakeholders of the innovation ecosystem - such as tech companies, start-ups, incubators, research centres and universities - and a promoter of new forms of entrepreneurship in accessing venture capital. Intesa Sanpaolo Innovation Center focuses mainly on circular economy, development of the most promising start-ups, venture capital investments of the management company Neva SGR and applied research

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Published: July 2024