FACTSHEET – ENERGY STORAGE

BACKGROUND

The energy transition requires a massive increase in investments. According to the 'Net Zero Emissions by 2050' (NZE) scenario[1] of the International Energy Agency (IEA), which is the most referenced scenario with low or no overshoot and limited reliance on negative emissions technologies, yearly investments in the "clean" energy transition must more than double and reach US$4.2 trillion by 2030. Meanwhile investments in fossil fuels must decrease and any support to their expansion must be stopped immediately. However, the role of certain energy sources and technologies should be nuanced. Consideration is particularly required when development is uncertain or associated with damaging social, environmental and climate impacts or risks, or poses too great a threat to the 1.5°C objective and global biodiversity protection targets.

This document discusses the potential of energy storage in the power sector transition. It is part of a series of factsheets that aim to guide the decisions of financial players wishing to contribute to a rapid and fair energy transition.

A new sustainable power system based in the majority on variable sources of energy, such as wind and solar, requires energy storage capacity. It is necessary both for hour-to-hour and daily fluctuations (short-term energy storage – STES) and for monthly and seasonal timescales (long-term energy storage – LTES).

KEY ELEMENT – STES

STES is used for hourly and daily balancing (generally less than four hours), generally through batteries. Batteries store power when production exceeds demand, and supply power when demand exceeds production. They can be regrouped in large-scale grid-connected installations or linked to off-grid systems at the smaller, local scale. In 2021, there were 16 gigawatts (GW) of grid-scale battery storage capacities around the world, mostly in developed countries and China.

In the NZE scenario, grid-scale battery storage capacity expands 44-fold between 2021 and 2030, from 16 GW to 680 GW. The storage addition pace accelerates from 6 GW added in 2021 to 140 GW added in 2030, with an average storage addition of 80 GW per year over the period. To reach these targets, global investment in battery energy storage must massively increase. In 2022, investments exceeded US$20 billion and the IEA estimates they will exceed US$35 billion in 2023,[2] but more efforts are needed.

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[1] IEA, World Energy Outlook, 2023.
[2] IEA, Grid-scale storage overview, accessed in November 2023.

Different types of batteries exist – two kinds are most suitable for grid-scale storage:

- **Lithium iron phosphate batteries** – a subset of lithium-ion batteries (Li-ion batteries). The development of these batteries is key to the energy transition. Li-ion batteries are currently in the early adoption phase,[3] due to their high performance and rapidly dropping costs, and are already used for many stationary power storage applications.[4] Depending on the technology, components of Li-ion batteries can include critical or near critical materials[5] in the medium-term, such as cobalt, graphite, lithium, nickel, and copper.

- **Redox flow batteries** – still in the commercial demonstration phase, these batteries are nonetheless important to the energy transition. Redox flow batteries (flow batteries after reduction-oxidation) could emerge as a breakthrough technology for stationary storage as they do not show performance degradation for 25-30 years and are capable of being sized according to energy storage needs with limited investment. Among redox flow batteries, hybrid flow batteries have a high potential and are composed of metals such as zinc, lead, iron, manganese, cadmium or chromium.

Category	Technology	Development Stage for Utility-Scale Grid Applications	Cost Range	Typical Duration of Discharge at Max Power Capacity	Reaction Time	Round-Trip Efficiency[3]	Lifetime
Electro-Chemical Batteries	Lithium-ion	Widely commercialized	1,408-1,947 ($/kW) 352-487 ($/kWh)†	Minutes to a few hours	Subsecond to seconds	86-88%	10 years
	Flow	Initial commercialization	1,995-2,438 ($/kW) 499-609 ($/kWh)†	Several hours	Subsecond to seconds	65%–70%	15 years
	Lead-acid	Widely commercialized	1,520-1,792 ($/kW) 380-448 ($/kWh)†	Minutes to a few hours	Seconds	79-85%	12 years
	Sodium-sulfur	Initial commercialization	2,394–5,170 ($/kW) 599–1,293 ($/kWh)††	Several hours	Subsecond	77%–83%	15 years

Figure 1: Qualitative comparison of energy storage technologies.
Source: Chen, et al. 2009; Mongird, et al. 2019; Mongird, et al. 2020.

KEY ELEMENTS – LTES

LTES is used to respond to power system variations that extend beyond hour-to-hour or daily fluctuations into monthly and seasonal timescales. Currently, pumped storage hydropower (PSH) is the largest source of LTES, with around 160 GW of installed capacity[6] in 2021 and representing the vast majority of current global storage capacity.[7] Between now and 2026, global installed PSH capacity is expected to increase by more than 40 GW, reaching a cumulative total of 200 GW, mainly due to the increased pumping capacity of existing plants.[8] In the IEA's scenarios,[9] PSH remains a key source of electricity storage capacity alongside batteries and is the second most important seasonal flexibility resource (after legacy thermal power plants).

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[3] Ibid.
[4] Li-ion batteries possess highly specific energy and power which results in a lightweight property and makes them suitable for lightweight applications. Elsevier, A comprehensive review of stationary energy storage devices for large scale renewable energy sources grid integration, Renewable and Sustainable Energy Reviews Volume 159, May 2022.
[5] Critical materials and near critical materials are materials with high importance to energy and high supply risk. Extracting critical materials can have environmental and social impacts due to water use, deforestation, waste management, child labor, gender inequalities, population displacement, safety conditions, etc.
[6] IEA, World Energy Outlook, 2022, page 310.
[7] In 2021, PSH accounted for 85% of the world's storage capacity (IEA, Hydropower special market report, July 2021).
[8] IEA, How rapidly will the global electricity storage market grow by 2026?, December 2021.
[9] IEA, Managing seasonal and interannual variability of renewables, April 2023.

In addition to PSH, hydrogen and ammonia are considered by the IEA as main emerging solutions for the seasonal storage of renewable electricity.[10] However, other forms of storage, such as thermal or mechanical systems, are under development and may emerge.

- **Mechanical systems** store potential or kinetic energy. They include gravity-based, compressed air (CAES) and liquid air (LAES) technologies.

- **Thermal systems** store thermal energy to release in the form of electricity or heat. There are different possible technologies (sensible heat, latent heat, thermochemical), and the most common storage media are solid beds made of materials such as rocks, pebbles or ceramics, hot water tanks or molten salts (often used with concentrating solar power plants).

For each of these mechanical and thermal technologies, many different configurations are possible, depending on the company developing them. Also, depending on the configuration, they have the potential to store energy for hours, weeks or even months, with a varying round-trip efficiency[11] from 30% to 90%.[12] The costs and readiness level of these mechanical and thermal technologies is also variable. In some cases, projects are at the stage of large-scale prototypes, while others are in the early stages of commercial adoption.[13] A summary table from the IEA showing a comparison between the key parameters for long-term storage technologies is shown below (see Table 2).

Research from Imperial College London[14] found that, overall, thermomechanical energy storage systems are already technically and economically competitive with PSH and batteries, particularly for medium- and long-term storage, although they are in the early stages of development. The authors believe there is significant potential for further progress. Other analyses show similar evidence.[15]

Technology	Power range	Storage capacity	Typical round-trip efficiency	TRL[2]
Pumped hydro	10 MW - 5 GW	0.2 - 0.5 GWh	70-85%	11
Compressed air (underground storage)	5 MW - 300 MW	0.2 - 1 GWh	41-75%	9
Thermal storage – low temperature	1 kW - 300 MW	n.a.	30-50%	8-9
Thermal storage – high temperature	1 - 60 MW	n.a.	80%	5-7
Gravitational	1 kW - 25 MW	100 MWh	80%	7
Electrolytic H_2 and gas turbine (GT) in combined cycle	Hundreds of MW	Unlimited	21%-27%	9*
Electrolytic ammonia and direct combustion in GT-combined cycle	Hundreds of MW	Unlimited	22%-24%	9*
Electrolytic H_2 and fuel cell	0.3 - 50 MW	Unlimited	30-50%	7-9

* In co-firing mode.

Table 2: Key parameters for long-duration electricity storage technologies.
Source: IEA, 2023.

[10] IEA, World Energy Outlook, 2022.
[11] This is the percentage of electricity put into storage and later retrieved.
[12] IEEE, Comparative Review of Energy Storage Systems, December 2018.
[13] Technology readiness levels (TRL) can be measured using the following scale: concept development 1-2-3, small prototype 4, large prototype 5-6, demonstration plant 7-8, early adoption 9-10, mature technology 11.
[14] Andreas V Olympios, et al. Progress and prospects of thermo-mechanical energy storage—a critical review, March 2021.
[15] For instance, see: IEEE, Comparative Review of Energy Storage Systems , December 2018; McKinsey, Net-zero power: Long-duration energy storage for a renewable grid, November 2022; and DNV, Closing the energy storage gap, 2023.

By 2021, more than 260 long duration power storage projects excluding PSH[16] have been announced worldwide at different commercial stages, according to the Long Duration Energy Storage Council. These projects total 5 GW and 65 GWh. Most of the announced capacity is associated with traditional molten salts (60%) and CAES technologies (around 30%). The IEA estimates that concentrated solar power (molten salts) is in the same range, with a storage expansion of 2.6 GW by 2026 – placing concentrated solar power as the LTES that will develop the most after PSH.[17]

In terms of environmental impacts, because of its characteristics – an absence of toxic chemicals and low dependence on geographical features – the environmental footprint of thermomechanical storage systems is expected to be considerably small.[18] However, as many of these systems involve very high temperatures and pressures, safety requirements can be significant.

RECLAIM FINANCE'S POSITION

In both cases, Reclaim Finance encourages financial institution to support research and development as well as investment in this sector. Reclaim Finance will examine the subject as it evolves.

On short-term storage

Reclaim Finance recommend investing in both li-ion and hybrid flow batteries as they are fundamental to the energy transition. In the shorter term, li-ion batteries are the most mature and will be a key element before 2030 to ensure a rapid transition.

Due to critical materials present in batteries, financial institutions should conduct a robust due diligence to ensure sustainable production of batteries all along the value chain, including the monitoring of environmental damages, respect of human rights – including acceptable working conditions, and transparency. The development of recycling must also be endorsed to improve the collection and reuse of critical materials and other key components.

On long-term storage

Reclaim Finance recommend investing in mechanical and thermal storage as they are fundamental to the energy transition. A combination of these technologies will be necessary, as the choice of a particular technology will depend on system preferences and design parameters, among other considerations. Similarly, monthly and seasonal storage needs will change according to several variables, including climatic and regional conditions.

Mechanical and thermal power storage technologies are still in the early stages of development and adoption. The faster their development, the less need there will be for legacy thermal power plants and hydrogen-based energy storage, freeing up hydrogen for other sectors where its use could be more efficient.[19]

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[16] The scope includes mechanical, thermal, electrochemical, and chemical technologies (power-to-gas-to-power). It excludes large-scale aboveground PSH projects. McKinsey, Net-zero power: Long-duration energy storage for a renewable grid, November 2022.
[17] IEA, How rapidly will the global electricity storage market grow by 2026?, December 2021.
[18] Andreas V Olympios, et al. Progress and prospects of thermo-mechanical energy storage—a critical review, March 2021.
[19] See Reclaim Finance's factsheet on hydrogen.