Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

IIEC International Institute for Energy Conservation

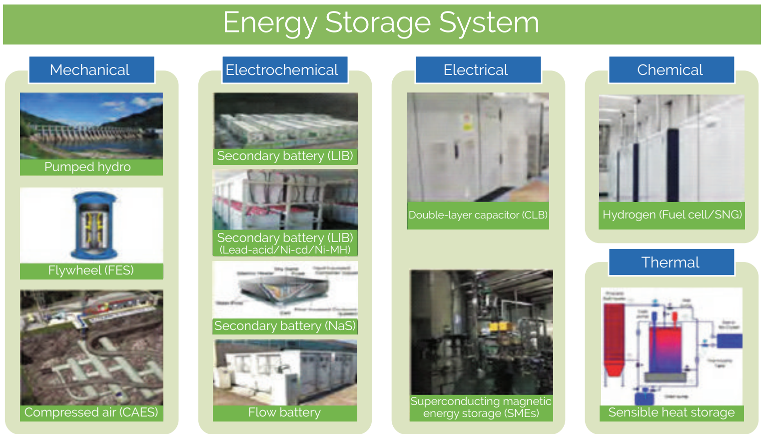
eds MEGHRAJ BASE

Source: KIUC

ENERGY Storage

Energy storage technologies include a large set of centralised and distributed designs that are capable of supplying an array of services to the energy system. Storage is one of a number of key technologies that can support decarbonisation. energy storage technologies are categorised by output: electricity and thermal (heat or cold). Technologies in both categories can serve as generators and consumers, giving them the potential to link currently disconnected energy markets (e.g. power, transportation fuels, and local heat markets). Broadly speaking, energy storage is a system integration technology that allows for the improved management of energy supply and demand. In many cases, a single unit of energy storage infrastructure can provide multiple valuable energy and power services.

Energy storage devices can be categorized as mechanical, electrochemical, chemical, electrical, or thermal devices, depending on the storage technology used (Figure below). Mechanical technology, including pumped hydropower generation, is the oldest technology. However, a limitation of this technology is its need for abundant water resources and a different geographic elevation, as well as the construction of power transmission lines to households that consume electricity.



*Mechanical, electrochemical, chemical, electrical, or thermal.
Li-ion=lithium-ion, Na-S = sodium-sulfer, Ni-CD = nickel-cadmium, Ni-MH = nickel-metal hydride, SMES=superconducting magnetic energy storage.

Source: Korea Battery Industry Association 2017 "Energy storage system technology and business model"

Energy Storage System (ESS) is fast emerging as an essential part of the evolving clean energy systems of the 21st century. Energy storage represents a huge economic opportunity for India. Ambitious goals, concerted strategies, and a collaborative approach could help India meet its emission reduction targets while avoiding import dependency for battery packs and cells.

India is committed to reducing emission intensity up to 33-35% from the 2005 level by 2030 and set the target of 40% non-fossil fuel-based electricity generation in the energy mix. This requires radical measures to scale up the share of renewable energy (RE) besides the ongoing program of 175 GW RE by 2022. The new targets for RE by 2030 could be in the order of 350 to 500 GW.

With ambitious plans to use renewables – particularly solar PV –to satisfy rapidly increasing electricity demand, India will be the country with the greatest need for additional flexibility in the coming decades, according to IEA analysis.

Table 1: Storage Technologies Comparison Matrix

	Hydro	Flywheel	Lead Acid	Ni–MH	Thermal	Li	Flow	Liquid Metal	Compressed Air	Super-capacitors
Specific energy (kW/kg)	0.3–1.33	5–200	30–50	30–90	10–250	90–250	10–90	100–240	3.2–60	1-30
Energy density (kWh/vol)	0.5–1.33	0.25–424	25–90	38.9–300	25–370	94–500	5.17–70	150–345	0.4–20	NA
Specific power (Wh/kg)	0.001–0.12	400–30,000	25–415	50–1,000	10–30	8–2,000	5.5–166	14.29–260	2.2–24	5
Cycle life (h)	20–50k	Indefinite	200–2k	300–10k	Indefinite	500–10k	10k+ 5k–	10k+ 5k–	20k+	30k
Life cycle	Near universal life with maintenance	Near universal life with maintenance	Useful life varies by depth of discharge and application, variations by chemistry	Allows deeper discharge and more stable storage, variations by chemistry	Thermal salts not yet proven. passive storage varies by technology	Useful life varies by depth of discharge and other applications, variations by chemistry	Moving parts require intermittent replacement	Not yet proven	Near universal life with maintenance	Near universal life with maintenance
Cost per kWh	$1–$291	$200–$150,000	$50–$1,100	$100–$1,000	$1–$137	$200–$4,000	$100–$2,000	$150–$900	$1–$140	$2,400-$6,000
Environmental impact	High/Mixed	Low	High	High/Medium	Low	High/Medium	Medium	Low	Low/Medium	Low
Pros	Large power capacity, positive externalities	Extremely fast response, high specific power, low cost, long life	Mature technology with established value proposition	Deep discharge capacity, reliable, high energy density	Could pair with waste heat generation, scalable, low cost, large scale	Flexible uses, very fast response and high specific power	Large storage capacity, cheap materials	High capacity, fast response, cheap materials, highly stable, temperature tolerant	Low cost, large scale, mature technology paired with gas turbines	Provide peak power and backup power. Extend battery run time and battery life. Reduce battery size, weight, and cost. Enable low/high temperature operation. Improve load balancing when used in parallel with a battery. Provide energy storage and source balancing when used with energy harvesters.

k = thousand, kg = kilogram, kWh = kilowatt-hour, Li = lithium, Ni–MH = nickel–metal hydride, W = watt.

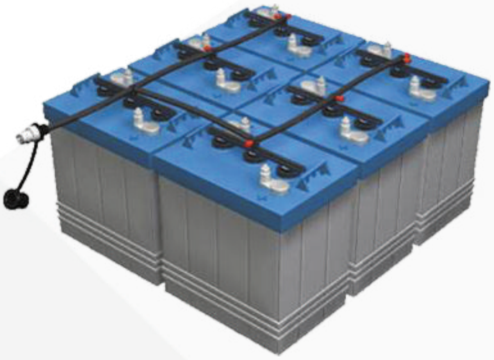
	Hydro	Flywheel	Lead Acid	Ni–MH	Thermal	Li	Flow	Liquid Metal	Compressed Air	Super-capacitors
Cons	Geo-graphically limited, expensive construc-tion, low energy density and environ-mentally damaging	Low energy density	Low life cycle, toxic materials, flamma-bility risk	Some toxic variations, less specific power than Li, high self-dis-charge, high memory effect	Not fully commer-cialized or not electri-fied	Safety concerns, low depth of corrosion, self-discharge, and efficiency loss over time	Space require-ments, eco-nomic efficiency in multiple applica-tions	Untested in commer-cial use, persis-tent tech-nology issues	Geo-graphically limited, not scalable	They have higher self-discharge rate. This is considerably high compare to battery. Individual cells have low voltages. Hence series connections are required to achieve higher voltages.

Figure 1: Range of Services that can be provided by electricity storage[1]

Bulk energy services	Ancillary services	Transmission infrastructure services	Distribution infrastructure services	Customer energy management services	Off-grid
Electric energy time shift (arbltrage)	Regulation	Transmission upgrade deferral	Distribution upgrade deferral	Power quality	Solar home systems
Electric supply capacity	Spinning, non-spinning and supplemental reserve	Transmission congestion relief	Voltage support	Power reliability	Mini-grids: System stability services
	Voltage support			Retail electric energy time shift	Mini-grids: Facilitating high share of VRE
	Black start			Demand charge management	
				Increased self-consumption of solar PV	

Boxes in red: Energy storage services directly supporting the integration of variable renewable energy

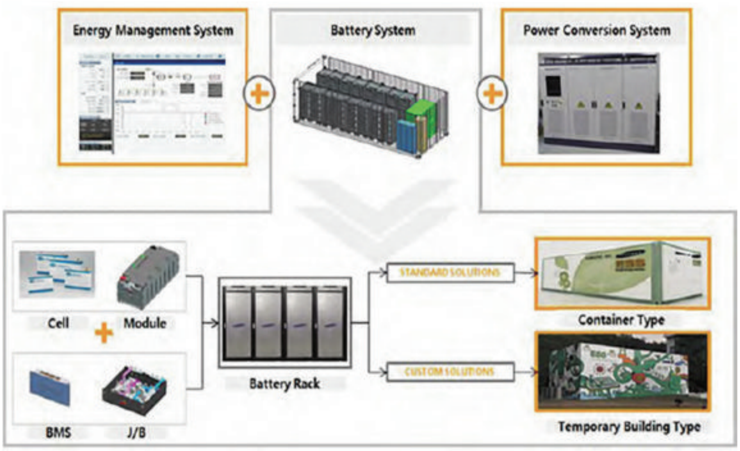
Batteries are ideally suited to meet these rising flexibility needs. Over the next two decades, global growth in batteries is set to outstrip that of any other flexibility option available to electricity systems, according to the World Energy Outlook 2019. Batteries have other advantages, too. They increase the value and competitiveness of solar PV by storing the electricity produced during sunny periods and feeding it back to the grid at another time. Battery storage, coupled with solar PV, also appears to be one of the most cost-effective ways of helping provide affordable electricity to isolated communities.[2]



[1] IRENA report
[2] https://www.leadingedgepower.com/support/help-with-batteries/battery-bank-wiring.html

The various components of a battery energy storage system are shown in the Figure below Schematic.

Figure 2: Schematic of A Battery Energy Storage System



BMS = battery management system, J/B = Junction box.
Source: Korea Battery Industry Association 2017 "Energy storage system technology and business model".

- The battery system consists of the battery pack, which connects multiple cells to appropriate voltage and capacity; the battery management (system BMS); and the battery thermal management system (B-TMS). The BMS protects the cells from harmful operation, in terms of voltage, temperature, and current, to achieve reliable and safe operation, and balances varying cell states-of-charge (SOCs) within a serial connection. The B-TMS controls the temperature of the cells according to their specifications in terms of absolute values and temperature gradients within the pack.

- The components required for the reliable operation of the overall system are system control and monitoring, the energy management system (EMS), and system thermal management. System control and monitoring is general (IT) monitoring, which is partly combined into the overall supervisory control and data acquisition (SCADA) system but may also include fire and distribution. System thermal management controls all functions related to the heating, ventilation, and air-conditioning of the containment system.

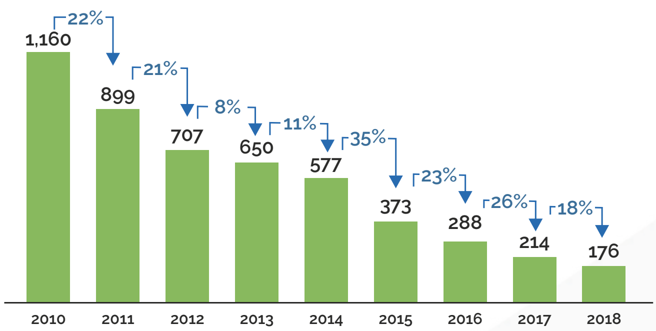
- The power electronics can be grouped into the conversion unit, which converts the power flow between the grid and the battery, and the required control and monitoring components—voltage sensing units and thermal management of power electronics components (fan cooling).

Combining Solar and batteries in India

Increasing deployment of variable renewables and changes in electricity demand patterns will double the global need to source power system flexibility, including from batteries. Under stated policies, renewables make up two-thirds of all additions to global power generation capacity through 2040, and solar PV becomes the largest source of installed capacity around 2035. These trends will drive a significant increase in the use of battery storage, led by India, which is projected to account for more than one-third of total deployment by 2040. However, in this scenario, CO2 emissions from the power sector remain stubbornly high around current levels of 13.8 billion tonnes and the sector remains one of the biggest sources of air pollution, especially in Asia.

Due to technological advancements and expected cost reductions, capital costs for battery storage are expected to decline by more than 50% by 2030, thus boosting the amount of storage that is economical to deploy in solar PV projects especially for commercial and big residential societies.

Figure 3: Average global lithium-ion battery pack price declines (Source: BNEF, 2019)



Source: *BloombergNEF*

Source: *Nextracker'*

Tata Power Collaborates with AES and Mitsubishi Corporation to Power Up South Asia's Largest Grid-Scale Energy Storage System in India

Tata Power, The AES Corporation and Mitsubishi Corporation inaugurated India's first grid-scale battery-based energy storage system in Rohini, Delhi. The 10-Megawatt grid-connected system, owned by AES and Mitsubishi Corporation will pave the path for wider adoption of grid-scale energy storage technology across India. Fluence, a market-leading supplier of energy storage technology jointly owned by Siemens and AES, supplied its state of the art Advancion Technology for the project.

Battery-based energy storage enables electricity to be stored and then delivered within milliseconds, reducing instability of the electric grid, and enabling more energy to be captured and delivered on demand. India has the ambitious vision of installing 225 GW of renewable energy generation by 2022. Battery-based energy storage provides the flexibility and agility to better integrate intermittent solar and wind energy resources into India's electric grid and ensure high-quality power for consumers. This 10 MW project is located at Tata Power Delhi Distribution Ltd.'s (Tata Power-DDL) sub-station in Rohini, Delhi and will provide grid stabilization, better peak load management, add system flexibility, enhance reliability and protect critical facilities for 2 million consumers served by the company.

Players in India

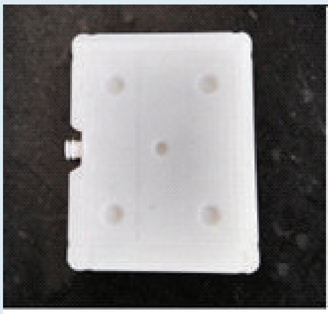
Pluss Advanced Technologies
Exide Industries Ltd, Luminous Power Technologies Pvt Ltd,
Okaya Power Ltd & Greenvision Technologies Pvt Ltd

PCM as thermal mass in building envelope

Increasingly, building designers are turning to help deliver sustainable outcomes. Thermal energy system can be applied in various methods; from storage of chilled water (Sensible energy) to ice/phase change materials (PCM) at a designed temperature (Latent energy) delivering results in a range of applications.

In an area that experiences a large diurnal temperature range, PCMs have the potential to be used to store substantial amounts of thermal energy high energy density to volume ratio. The peak daily temperature occurs in the afternoon and similarly, the minimum daily temperature occurs substantially after midnight.

A small change of temperature difference can charge or in other words activate the PCM. For instance, a PCM which has phase change point at +220C would require exposure to an air temperature of +170C. As the human comfort range is from 24 - 260C, the PCM to be used should be in melting range of 22-240C. For instance, PCMs savE® HS22 or savE® HS24 are salt which can change phase between 220C and 240C respectively. By comparison with the same temperature limitations, a conventional sensible heat storage system such as water or concrete would occupy a volume several times greater than latent heat storage. PCM systems can be developed using a wide range of encapsulations, including flexible pouches, HDPE containers as shown in figure next page.



PCM filled thermoTab

thermoTab in ceiling tiles

PCM filled pouches

Pouches in ceiling tiles

To keep a space cold or avoid the temperature increase beyond a certain limit, there are three ways i.e. reduction of heat gain inside the room, reduction in temperature fluctuations and improvement of heat rejection. Implementations of PCMs are the best way to reduce the temperature fluctuations and these can be applied in

buildings in either of the two ways: active or passive or a combination of both. The passive way of cooling is easier to implement and use as there is no requirement of mechanical equipment and additional energy. Only natural ventilation helps in charging the PCM by bringing the cold inside the room during the night.

Commercial application(Institutions/Office/Shopping centres)

Sample calculation of PCM required for a space having floor size of 50mtrs x 200 mtrs.

Input Criteria / parameters

- Floor area: 10,000 sq.m;
- PCM: Hs22;
- Density: 1540 kg/m3;
- Thickness: 17 mm;
- Latent heat: 167.6 kJ/kg;
- PCM module, Dimension, PCM weight and encapsulation type - 570 x 157 mm, 1.4Kg, 3-celled pouches
- using nylon multi-layered film.

In a single 60 x 60 cm false ceiling 3 units of such PCM pouches can fit. Hence, the amount of PCM coverage in one false ceiling will be 1.4 kg x 3 modules = 4.2 kg/false ceiling. The surface area of a single false ceiling is 0.37 sq.m. Therefore, the amount of PCM required per sq.m will be 11.35 kg.

- Incorporable weight of PCM in a 10,000 sq.m space - 10000 sq.m x 11.35 kg/sq.m = **1,13,500 kg**
- The total energy storage (PCM) capacity - 1,13,500 x 167.6 = 1,90,22,600 kJ = 5,284.05 Kw-h = **1501.15**

TRH

Reference to data from American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) we have assumed the average HVAC load per sq.mtr as 0.038 TR/sq.mtr(135 Watt/sqr.mtr).
Hence, a building of 10,000 sq.mtr would have an average heat load of 380 TR. Assuming 12 operational hours

per day the cumulative cooling capacity would be 4560 TRH. Based on the above scenario the PCM offers opportunity to shift up to 33% of the HVAC load towards free cooling for an average of 4 to 5 months in a year. If accounted for in the beginning of the project the capital equipment such as chillers, AHUs, ducts, pumping system can be downsized.

Selection of the right Phase Change Material

The selection of the right Phase Change Materials (PCM) may vary depending on the average minimum temperature of the region.
Three commonly used temperatures are;
SavE® HS 22 - Requires minimum air temperature of +17˚C
SavE® HS 24 - Requires minimum air temperature of +19˚C
SavE® HS 29 - Requires minimum air temperature of +24˚C