Summary Table of Alternate Batteries

Our lexicons list weird and wonderful batteries, but as with animal species, not all become house pets. A battery has stringent requirements. No less than eight requirements must be met to call a battery a battery. (See BU-104c: The Octagon Battery) Table 1 summarizes the less common batteries that serve various niche markets.

Chemistry	Sodium-sulfur; Sodium-nickel-chloride (ZEBRA)	Zinc-air (Primary and secondary)	Silver-zinc; Silver-oxide	Reusable Alkaline
Type	Molten-salt (Na) and sulfur (S). Economical with larger sizes, (Symbol NaS)	Mainly primary; shares similarity with fuel cell	Silver-zinc is rechargeable; silver-oxide is primary	Disposable alkaline made reusable at a similar cost to regular types
Voltage per cell	2.58V	1.40–1.65V	1.60V	1.50V
Specific Energy	90–120Wh/kg	300–400Wh/kg	250Wh/kg	200Wh/kg, less with each subsequent recharge
Activation	Operate at 270–350°C	Removal of seal enables airflow	Instant	Instant
Charging	Overnight charge	Charging by replacement of zinc electrodes	Similar to Li-ion	Voltage limiting (1.60–1.70V)
Discharging	High power burst	Low load	Similar to Li-ion	Low load (200–400mA)
Cycle life	3,000 cycles; 8 years	Once activated, battery is being consumed	Short cycle life; 2 year life span	50, depending on DoD. Recharge often
Maintenance	Keep battery hot	Only activate when needed	Keep inventory low	Do not discharge too low

Chemistry	Sodium-sulfur; Sodium-nickel-chloride (ZEBRA)	Zinc-air (Primary and secondary)	Silver-zinc; Silver-oxide	Reusable Alkaline
Failure modes	Electrical shorts due to corrosion	Sensitive to cold heat, humidity and air pollution	Zinc electrode and separator decay; cycling causes dendrite formation	50% capacity drop with 2nd charge; rising int-ernal resistance
Packaging	Large systems of 10kWh and higher	Mostly small sizes	Button cells (silver-zinc)	AA, AAA, C, D, 9V
History	Conceived by Germans in World War II; NaS gained new interest in 1970s	"Breathing" discovered by Leclanché in 1878, offered to buyers in 1932	Spacecraft use because of high capacity. (Now replaced by Li-ion)	Introduced in 1992, alternate to disposables. Leak-proof
Applications	Primary: One-shot missiles; Secondary: UPS, load- leveling, EV (Think City), delivery vans	Hearing aids; large units for railway signaling, mines safety lamps	Primary: Watches, memory backup; Secondary: Aerospace, missiles, military, TV cameras	Flashlights, toys, entertainment devices
Comments	Heating consumes 14% of battery energy per day	High capacity, low cost but only one-time use	New designs show capacity gain over Li-ion: expensive raw material	Regular alkaline should not be charged; danger of leakage, gas, explosion

Table 1: *Summary of most common alternative batteries and equivalent.*

Detailed information is on BU-211: Alternate Battery Systems. All readings are estimated and may vary with different versions and newer developments.

Table 2 touches on semi-batteries. They are listed because of similarities with the electrochemical reaction of a real battery. What was once a unique device standing on its own is now merging with the battery, and the supercapacitor is such an example. The fuel cell has similarities also in that it is a battery in reverse. Overcharging a battery turns water into hydrogens and oxygen (gassing); the fuel cell produces electricity and water by combining hydrogens and oxygen.

Chemistry	Supercapacitor	Flow Battery	Fuel Cell
Type	Double-layer capacitor. Stores energy by static charge as opposed to electrochemical reaction	Rechargeable; pump operated, electrolyte stored in tank	Combining hydrogen and oxygen produces electricity
Voltage per cell	Limited at 2.30–2.75V	1.15–1.55V	0.6–0.8V
Specific Energy	5Wh/kg (typical)	40Wh/kg	40Wh/kg
Activation	Instant	sluggish ramp-up	sluggish ramp-up
Charging	1–10s; simple charging, current stops when full	Overnight charge	Hydrogen feed through tank
Discharging	Very high power	Low load current	Low load current
Cycle life	1 million; 10–15 years	10,000 cycles; 20 years.	2,000–4,000h; stationary up to 40,000 hours
Maintenance	Low maintenance	High	High
Failure modes	Exceeding voltage limits lowers service life	High corrosion. Vanadium keeps corrosion under control	Stack damages by freezing and heat; capacity fade by cycling.
Packaging	Mostly in cylindrical formats	Large systems; 20kWh and up	Large, also portable
Environment	Broad temperature range. Non-toxic.	Functions more like a refinery than a battery	Must have correct moisture content. Cannot freeze.
History	GE experimented in 1956; Standard Oil discovered double layer in 1966; NEC commercialized it in 1978	First patent in 1954. Current types patented in 1986	William Grove, developed in 1839; space program 1960s
Applications	Memory backup, generator start, large MW systems. In competition with flywheel	Large energy storage system; economical with large size	Forklift, EV, UPS, portable usage in military
Comments	Expensive per Wh. Some argue to spend the money on a larger battery	Capacity set by tank size; can be enlarged if so needed	Clean but expensive; poor power band

Table 2: *Summary of most batteries that deviate from the electro-chemical concept of a battery.*

Readings are estimated and may vary with different versions and newer developments. All readings are estimated average at time of publication. Detailed information is on:

- BU-209: How does a Supercapacitor Work?
- BU-210b: How does the Flow Battery work?
- BU-210: How does the Fuel Cell Work?

Last Updated: 25-Oct-2021