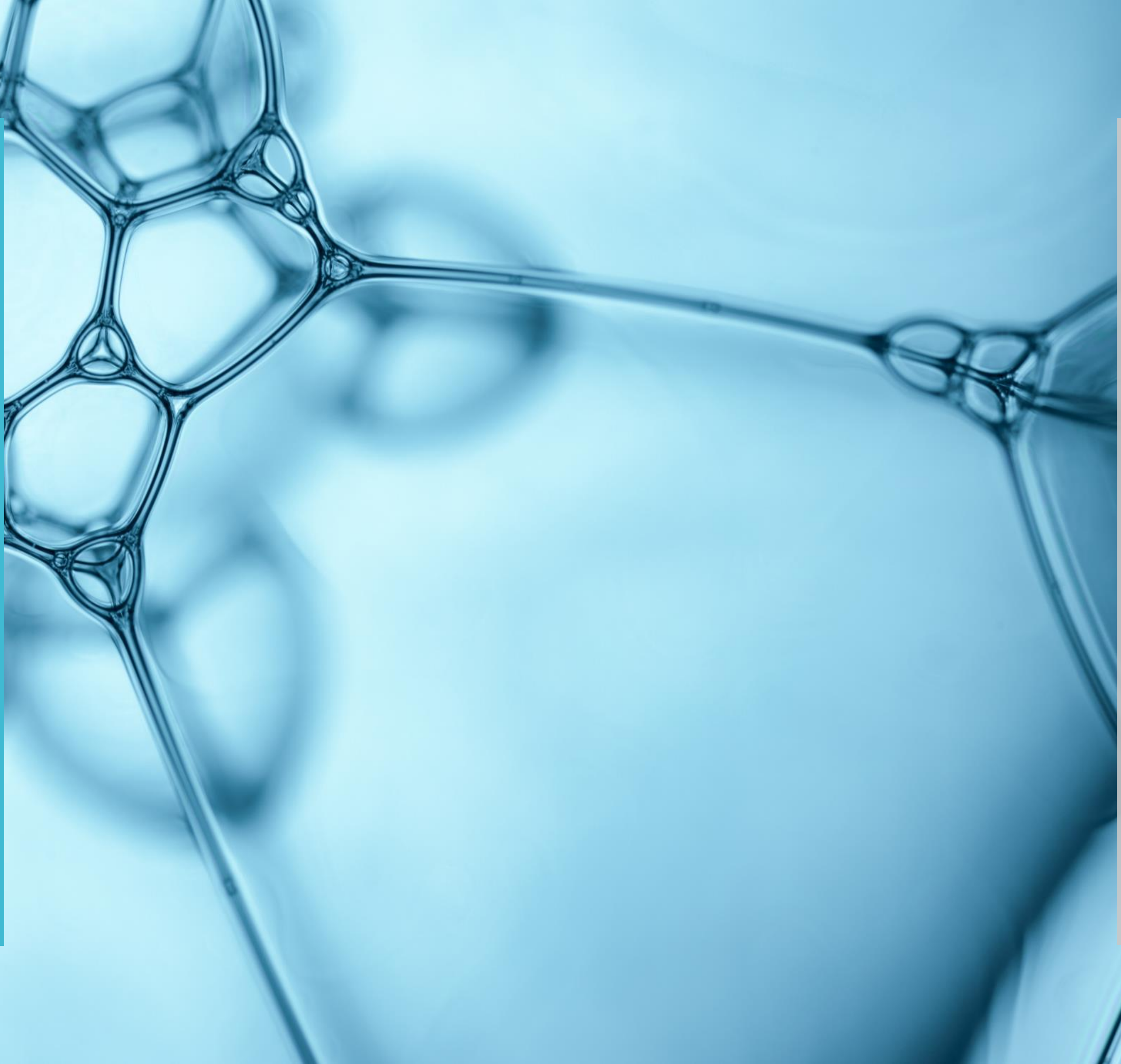
Sistemas de Almacenamiento de Energía

Porque no todo son baterías…

Laima Klemas

Abril 30 de 2021



¿QUÉ ES LA ENERGÍA?

¿QUÉ TIPOS DE ENERGÍA CONOCE?

¿QUÉ ES ALMACENAMIENTO DE ENERGÍA?

EL ALMACENAMIENTO DE ENERGÍA, COMO CONCEPTO, SE COMPONE DE 3 PROCESOS:

1. GUARDAR (CARGARSE)
2. ALMACENAR
3. ENTREGAR (DESCARGARSE)

ALMACENAMIENTO PRIMARIO: Carga y descarga UNA SOLA VEZ

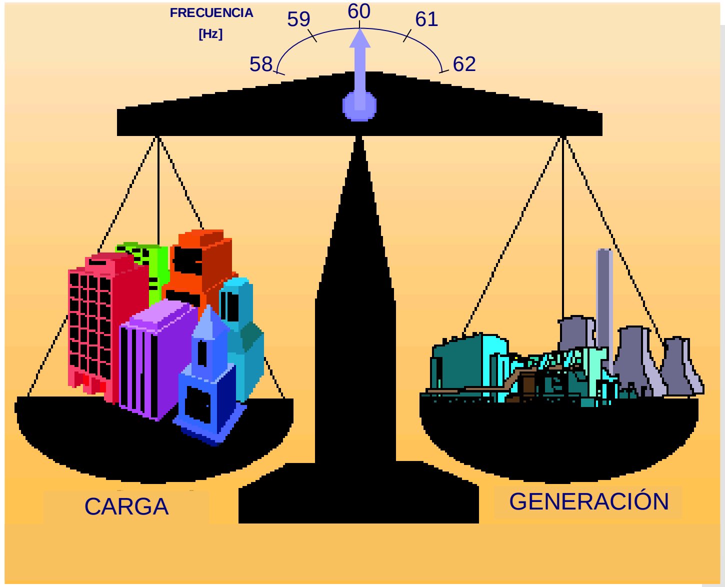
ALMACENAMIENTO SECUNDARIO: Carga y descarga MUUUUCHAS VECES

SISTEMA DE ALMACENAMIENTO DE ENERGÍA

“sustancia (electrolito, agua, gas, etc.) que tiene la energía almacenada y que la utilizo cuando a mi me sea mas conveniente”

¿Para qué necesitamos almacenar la energía?

1. COMPENSACIÓN DE LA GENERACIÓN
   - Excedentes
   - Déficit
   - Demanda a satisfacer



2. MERCADOS DE ENERGÍA
   - Precios de la energía en la bolsa
   - Precios de la energía fuera de la bolsa (mercado spot, contratos, etc.)

Clasificación (física) de Sistemas de Almacenamiento

Formas de almacenamiento de energía

- Mecánica
  - Bombeo agua
    - Hidroeléctricas
    - Tanques o reservorios
  - Aire/gas comprimido
  - Volantes de inercia
  - GRAVITACIONAL
- Térmica
  - Sales fundidas o MSES
  - Cambio de fase
  - Termo-químico
- Electro-química
  - Baterías
    - Iones de Litio
    - Plomo
    - Otras químicas
  - Baterías de flujo
  - Baterías de aire
  - Celdas de hidrógeno
- Electro-magnética
  - Superconducting magnetic ES o BOBINA SUPRACONDUCTORA
- Eléctrica
  - (súper) Capacitores o Condensadores

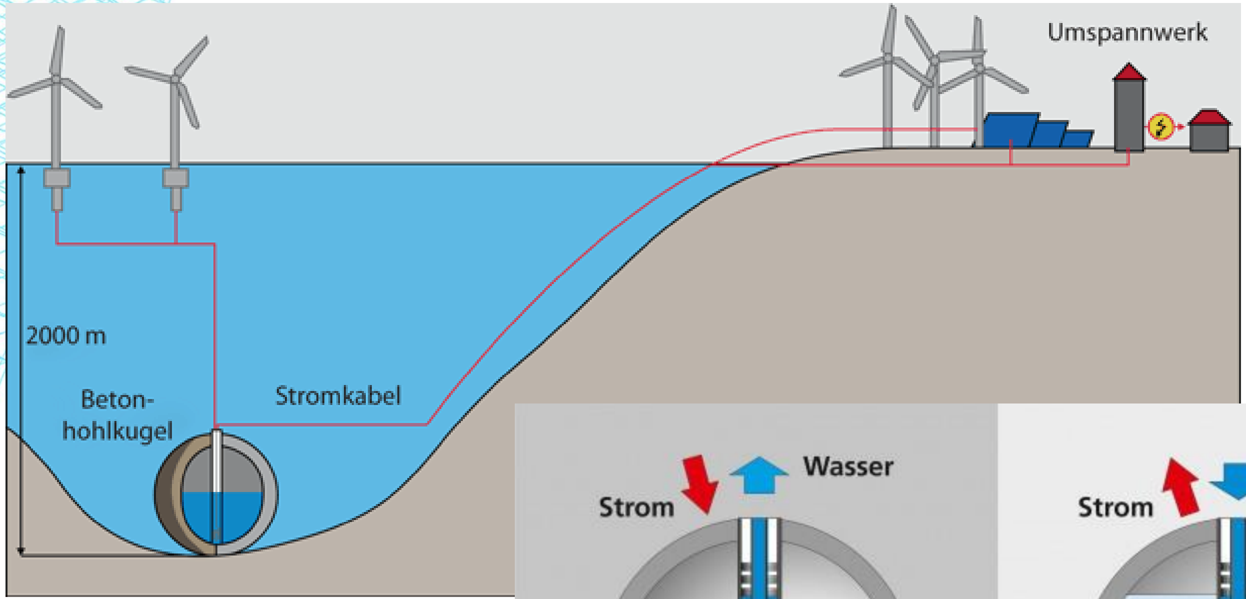
Corto (15 min) — Mediano (1 a 10 horas) — Largo (> 50 horas)

Tecnologías de Sistemas de Almacenamiento y Ejemplos Reales

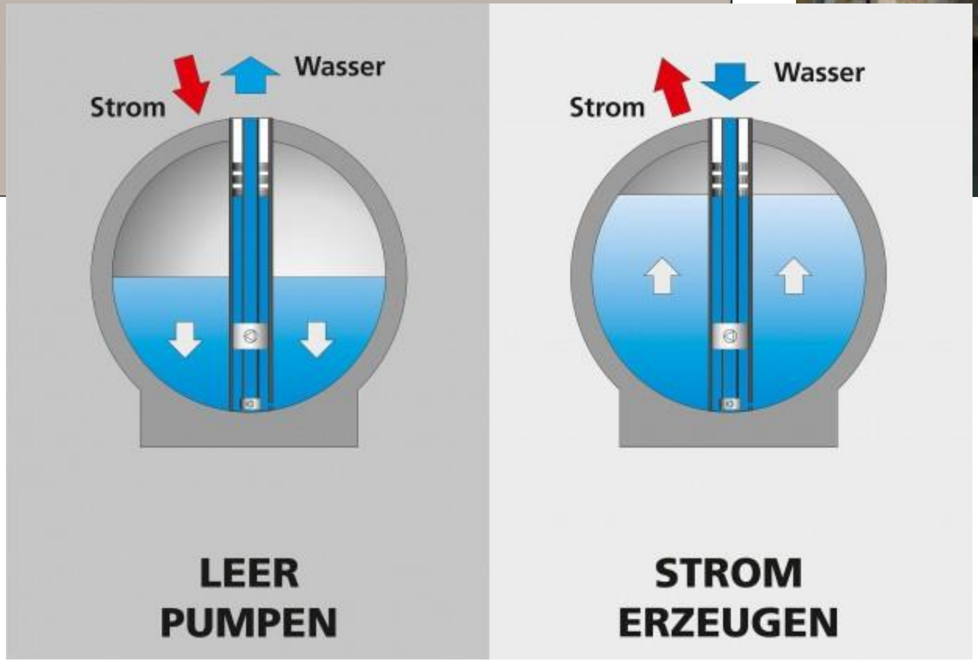
MECÁNICA: BOMBEO DE AGUA

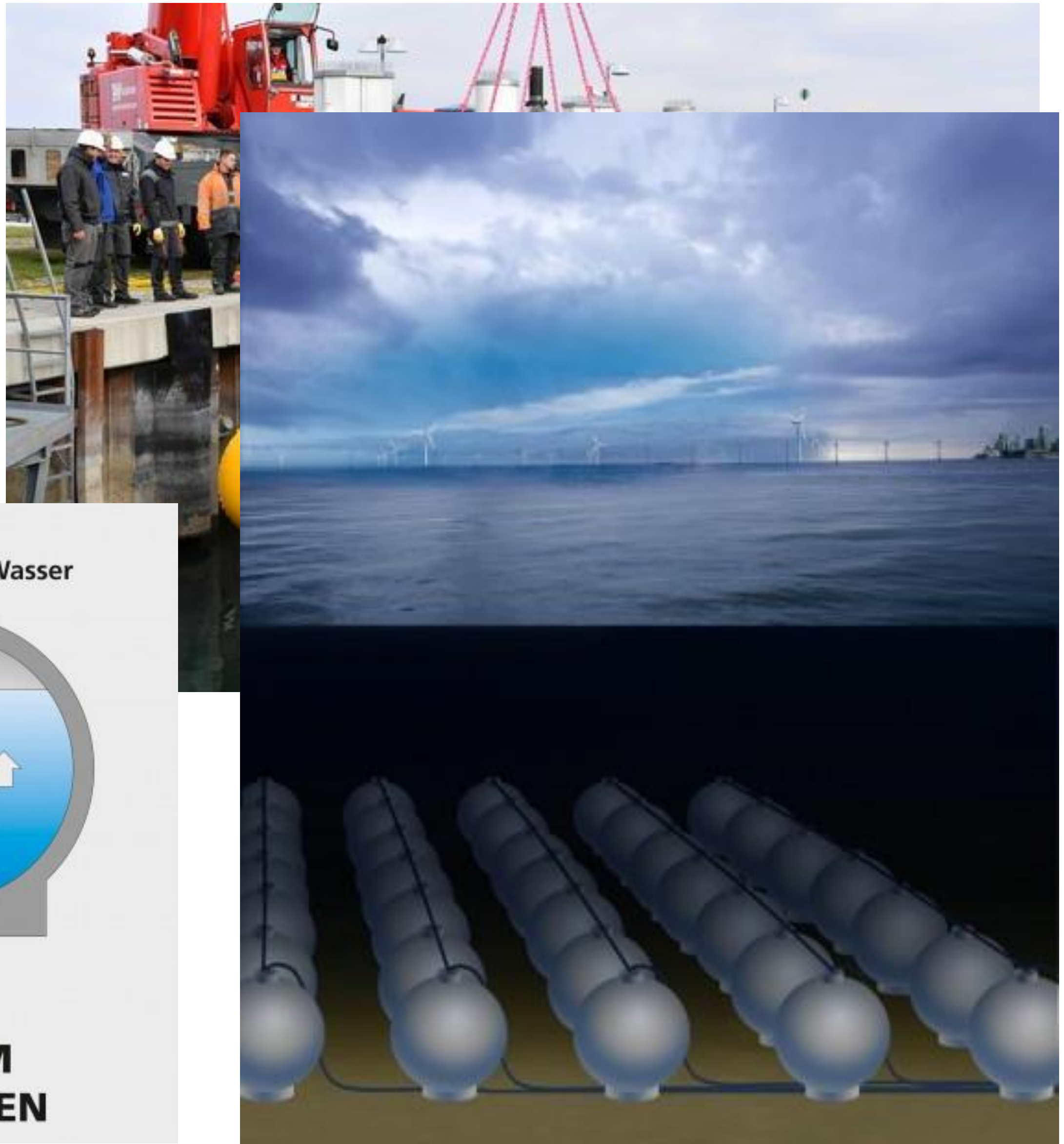
- **Almacenamiento con bombas**
- Almacenamiento con muro en anillo
- Almacenamiento con bombas de bola
- Almacenamiento con represamiento escalonado
- Almacenamiento subterráneo (minas)
- Almacenamiento de bombas a cielo abierto (minas)
- Almacenamiento de bomba Halden (minas)

MECÁNICA: ALMACENAMIENTO CON BOMBAS DE BOLA

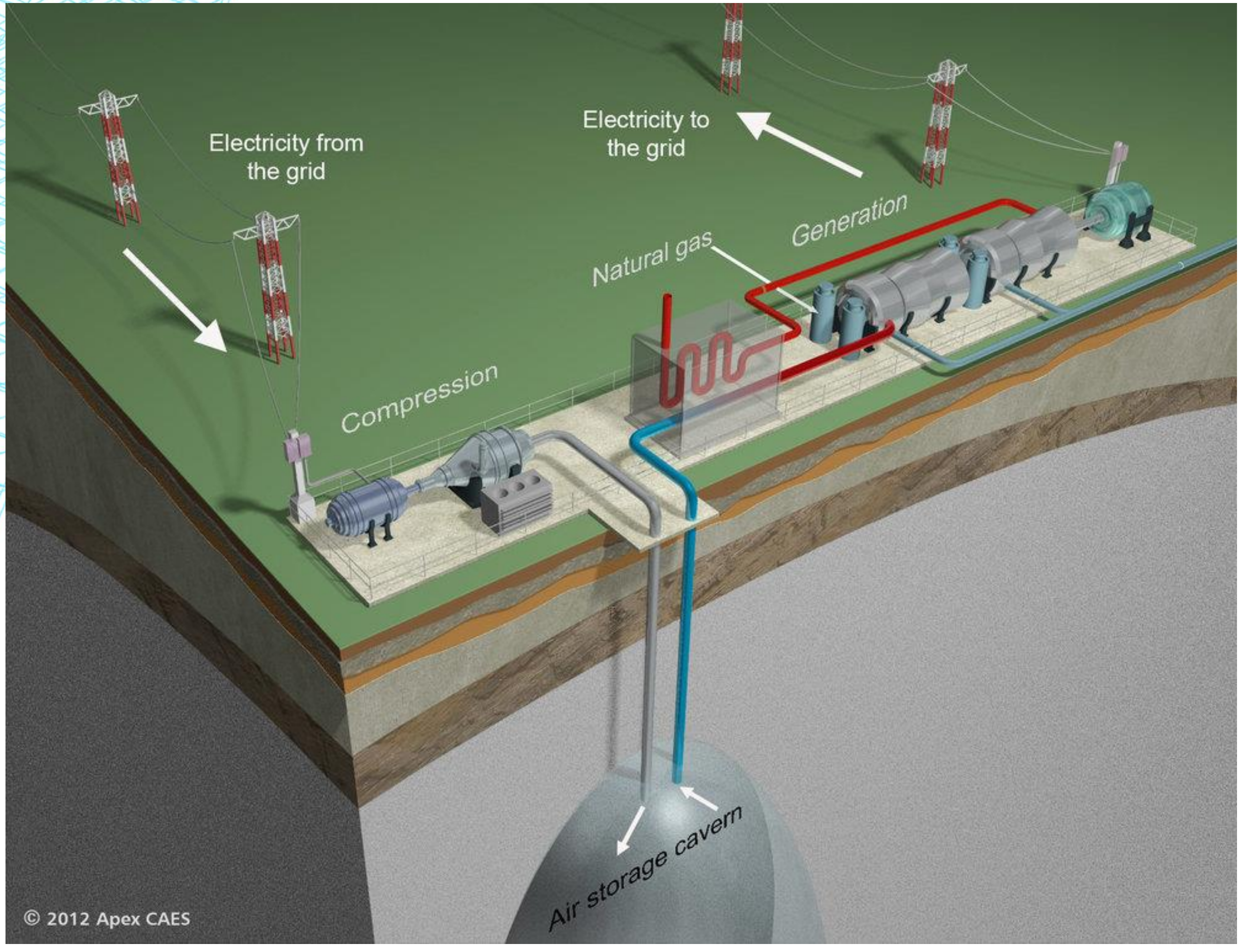


Fuente: Fraunhofer IWES

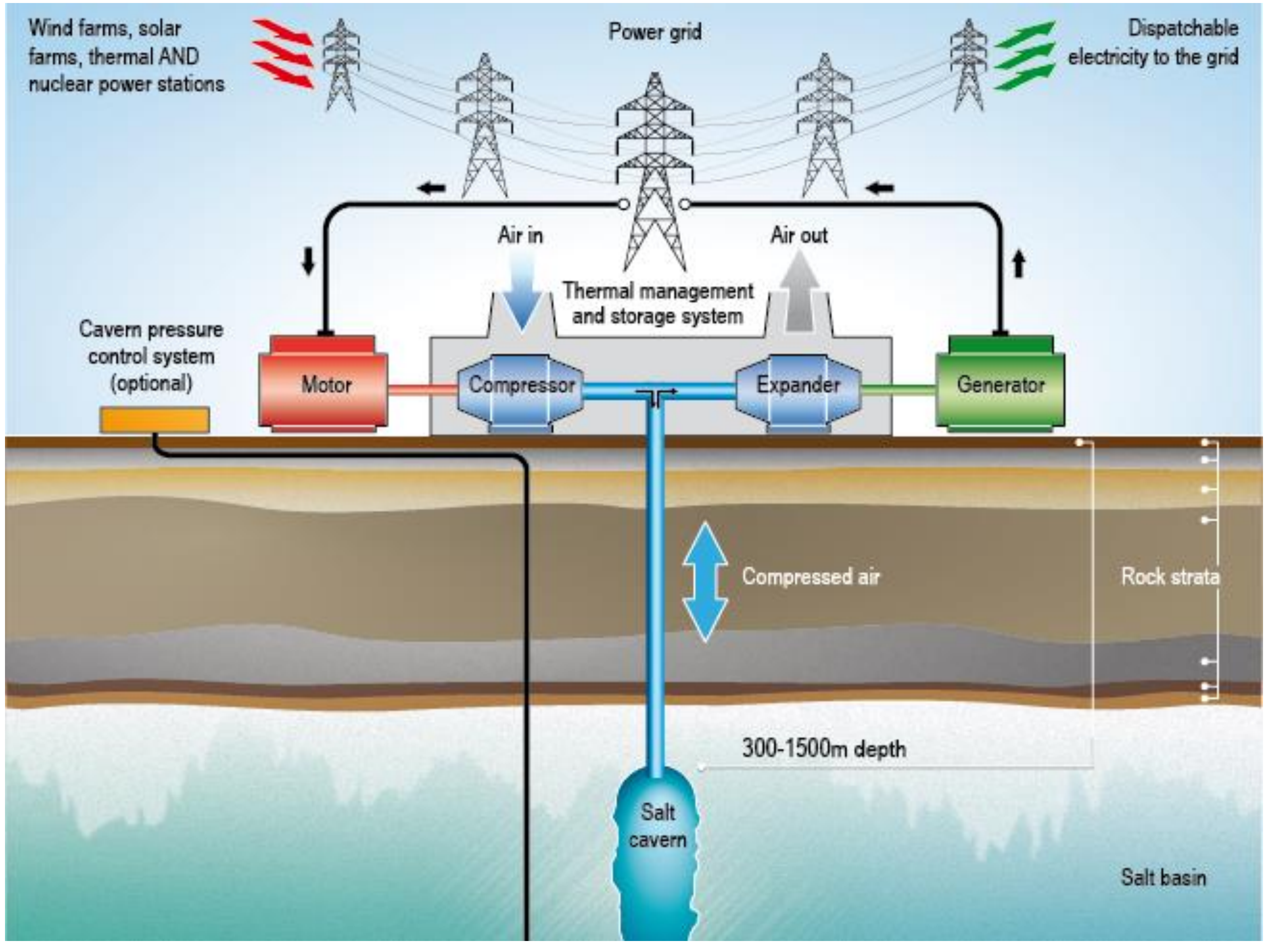




MECÁNICA: AIRE COMPRIMIDO

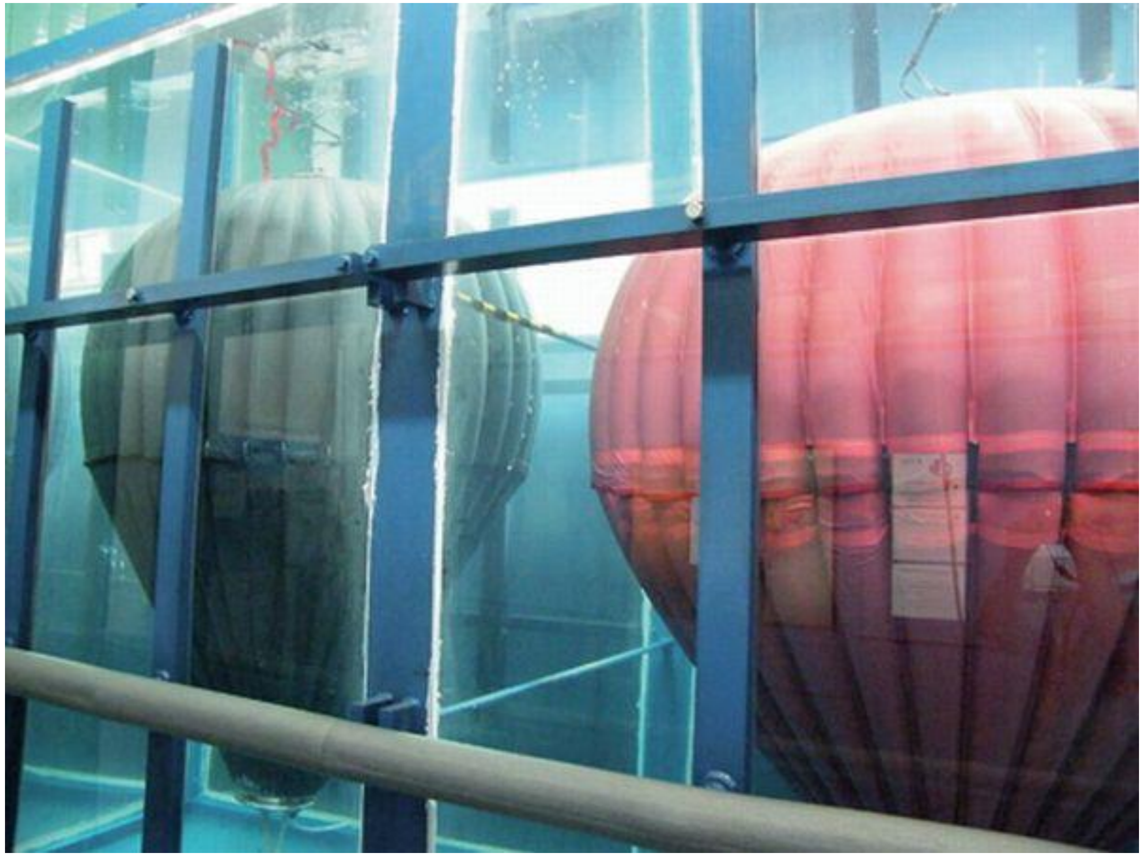


Fuente: https://interestingengineering.com/compressed-air-energy-storage-caes-systems



Fuente: https://www.oilfree-air.eu/compressed-air-energy-storage-caes/

MECÁNICA: AIRE COMPRIMIDO

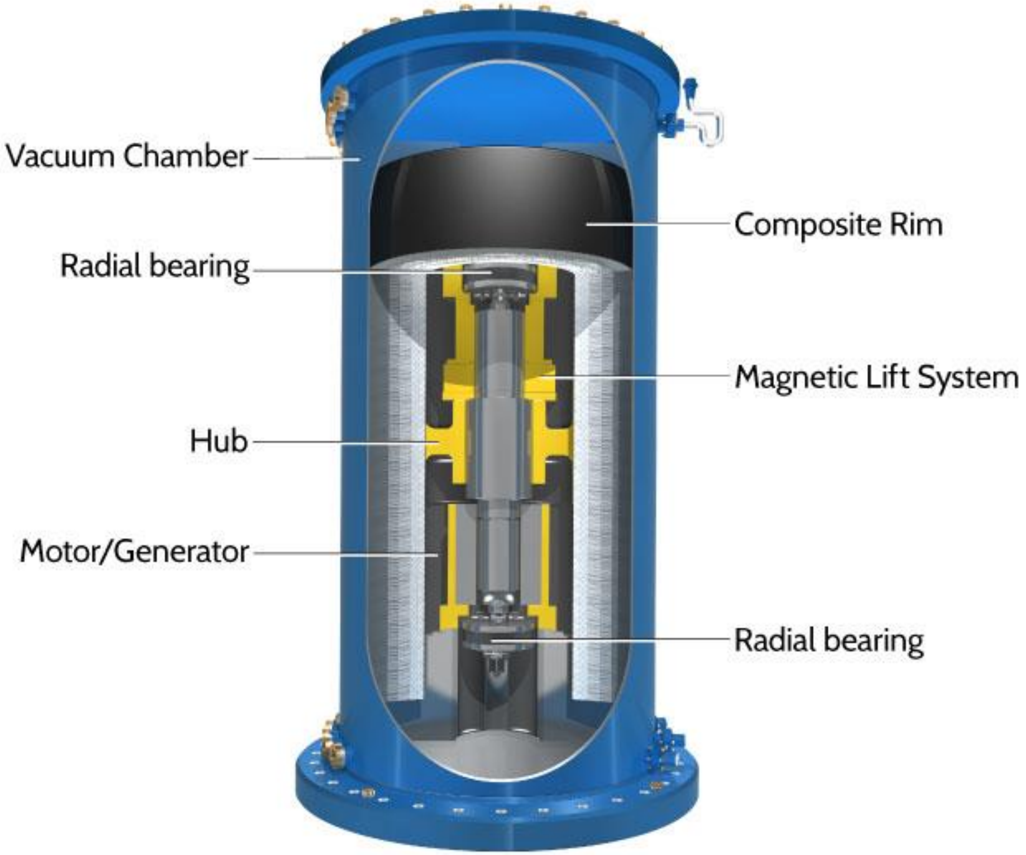


MECÁNICA: GAS NATURAL COMPRIMIDO

¿En dónde se inyecta o se almacena el gas?

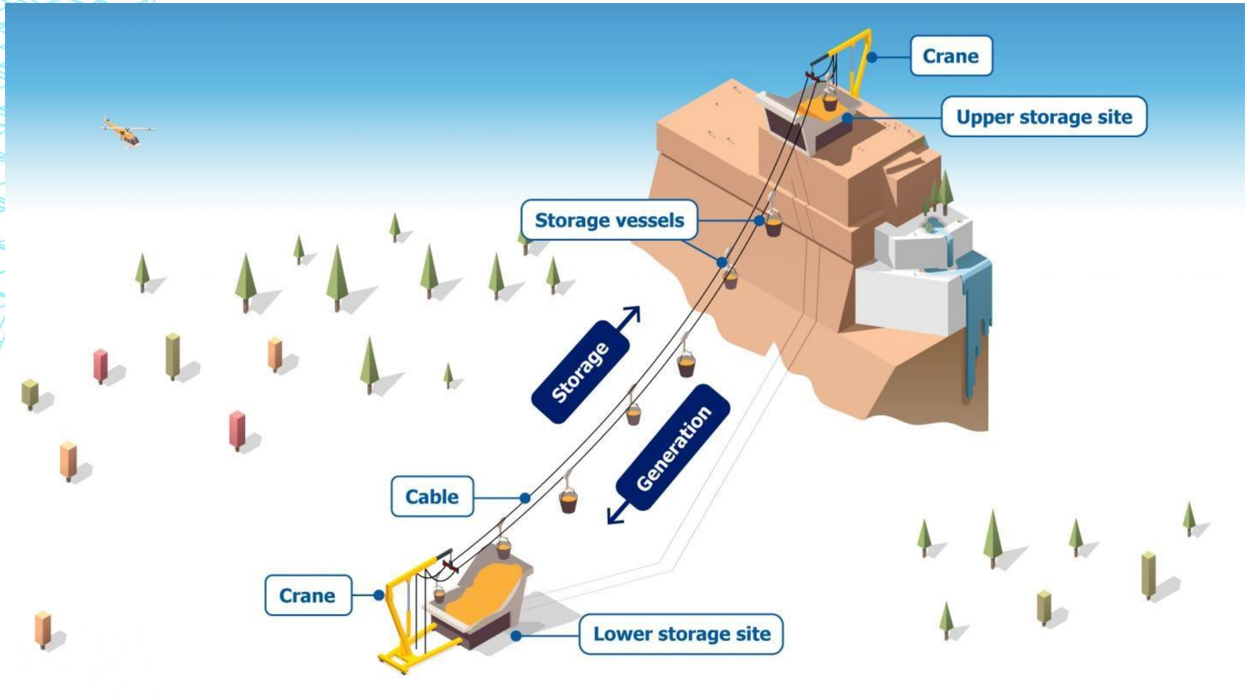
1. Rocas porosas que están de forma natural llenas de agua: almacenamiento en Reservorio ACUÍFERO
2. Cavernas de minas de sal ya explotadas: almacenamiento en cavernas de sal (impermeabilidad natural)
3. Cavernas artificiales
4. Cavernas naturales con recubrimiento adicional: almacenamiento en caverna roca
5. En pozos o yacimientos de gas que ya no son explotados: almacenamiento en “depleted gas reservoir
6. Contenedores de gas SOBRE suelo (gasómetro o contenedores esféricos)
7. Tanque almacenamiento tubular CERCA al suelo

MECÁNICA: VOLANTES DE INERCIA



Fuente: https://beaconpower.com/carbon-fiber-flywheels/

MECÁNICA: GRAVITACIONAL



Mountain Gravity Energy Storage (MGES)

Fuente: Energy Vault

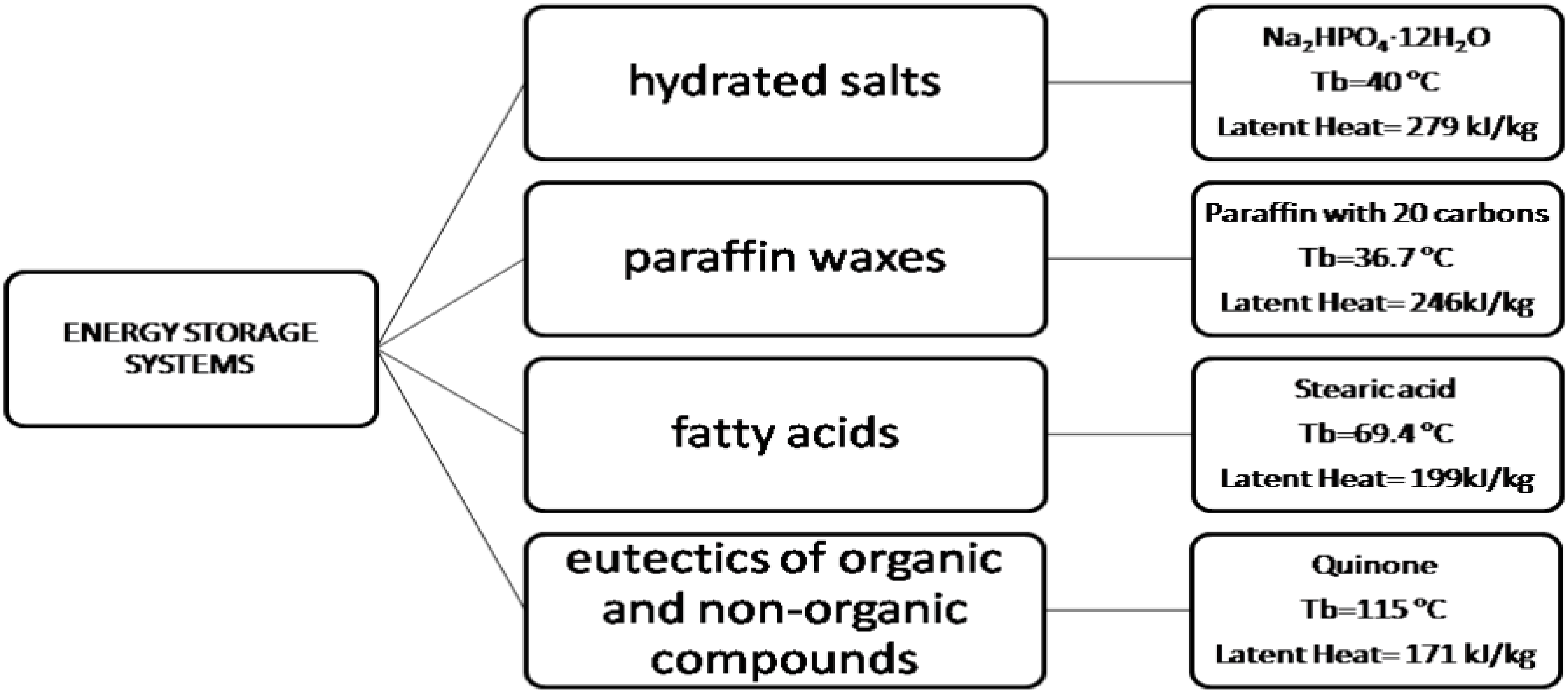
TÉRMICA: SALES FUNDIDAS

- El “electrolito” es SAL FUNDIDA
- Se almacena el CALOR SENSIBLE
- Complejo porque la extracción de calor debe ser a T = kte
- Tener en cuenta el calor específico
- Se almacenan en tanques o en cavernas rocosas

NOTA: silicio sólido o fundido es otro material interesante. Aluminio reciclado fundido también (Suecos: AZELIO)

Fuente: https://www.evwind.es/2019/10/16/molten-salt-storage-in-concentrated-solar-power-plants-could-meet-the-electricity-on-demand-role-of-coal-and-gas/71351

TÉRMICA: MATERIALES CON CAMBIO DE FASE



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ELECTRO-QUÍMICO: BATERÍAS

BATERÍA PRIMARIA

- RX IRREVERSIBLE
- NO RECARGABLE

BATERÍA SECUNDARIA

- RX REVERSIBLE
- RECARGABLE

Fuente: https://www.neoteo.com/baterias-recargables-con-celdas-solares-diy-14867/

ELECTRO-QUÍMICO: BATERÍAS TIPOS

Primarias

- **Alkaline battery (zinc manganese oxide, carbon)**
- Aluminium–air battery
- Atomic battery
  - Radioisotope thermoelectric generator
  - Betavoltaic device
- Bunsen cell
- Chromic acid cell (Poggendorff cell)
- Clark cell
- Daniell cell
- Dry cell
- Earth battery
- Frog battery

Primarias

- Galvanic cell
- Grove cell
- Leclanché cell
- Lemon/potato battery
- **Lithium battery**
- Lithium air battery
- Magnesium battery
- **Mercury battery**
- Molten salt battery
- Nickel oxyhydroxide battery
  - Oxyride battery
- Organic radical battery
- Paper battery

Fuente: https://en.wikipedia.org/wiki/List_of_battery_types

ELECTRO-QUÍMICO: BATERÍAS TIPOS

Primarias

- Pulvermacher's chain
- Silver-oxide battery
- Solid-state battery
- Sugar battery
- Voltaic pile
  - Penny battery
  - Trough battery
- Water-activated battery
- Weston cell
- **Zinc–air battery**
- Zinc–carbon battery
- Zinc chloride battery

Fuente: https://en.wikipedia.org/wiki/List_of_battery_types

ELECTRO-QUÍMICO: BATERÍAS TIPOS

Secundarias

- Aluminium-ion battery
- Calcium battery[1]
- **Flow battery**
  - Vanadium redox battery
  - Zinc–bromine battery
  - Zinc–cerium battery
- **Lead–acid battery**
  - **Deep cycle battery**
  - **VRLA battery**
  - **AGM battery**
  - Gel battery
- Glass battery

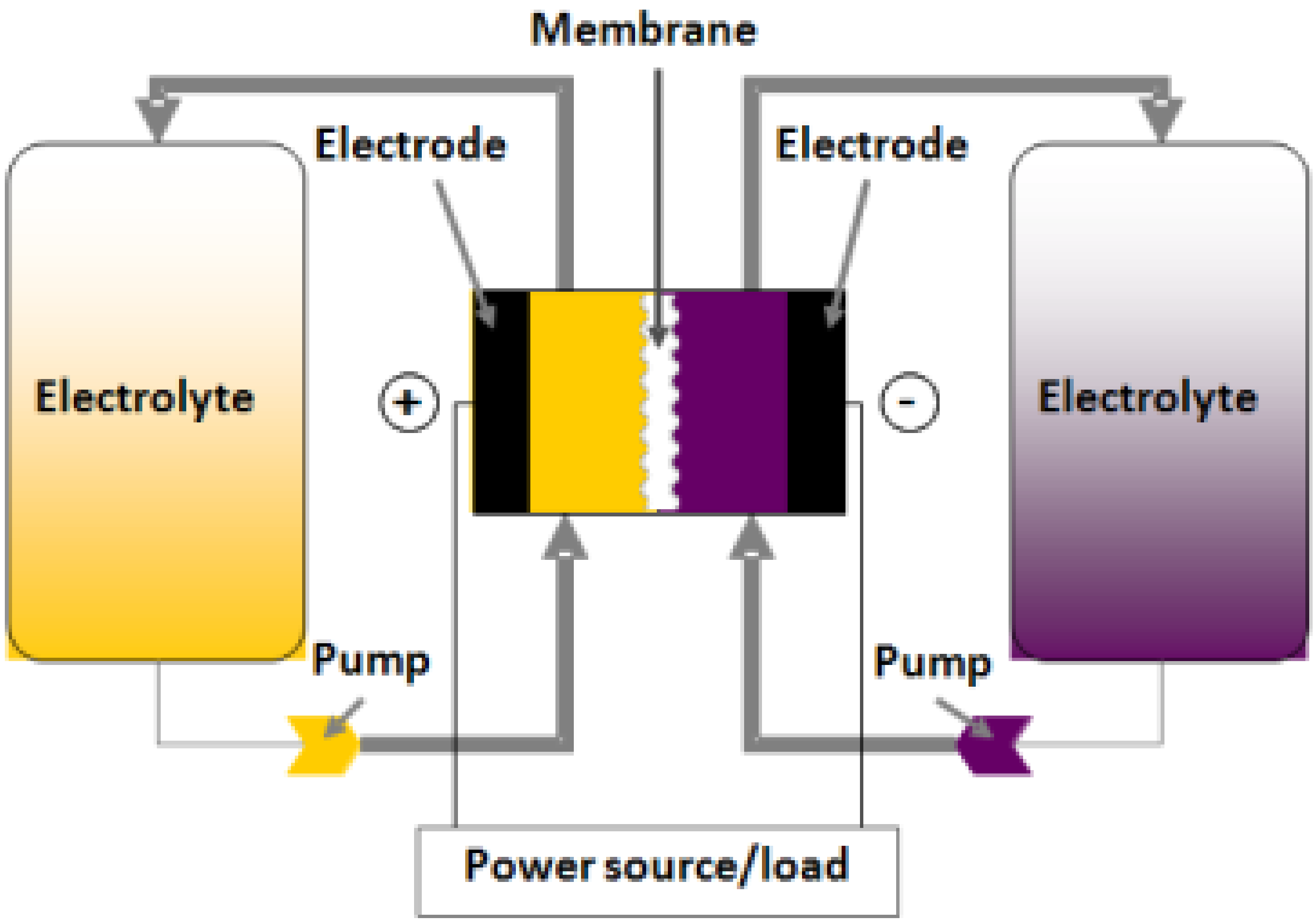
Secundarias

- **Lithium-ion battery**
  - Lithium ion lithium cobalt oxide battery (ICR)
  - Lithium–silicon battery
  - Lithium ion manganese oxide battery (LMO)
  - **Lithium ion polymer battery (LiPo)**
  - ***Lithium iron phosphate battery (LFP)***
  - Lithium nickel manganese cobalt oxides (NMC)
  - Lithium nickel cobalt aluminium oxides (NCA)
  - Lithium–sulfur battery
  - Lithium–titanate battery (LTO)
  - Thin film lithium-ion battery
  - Lithium ceramic battery

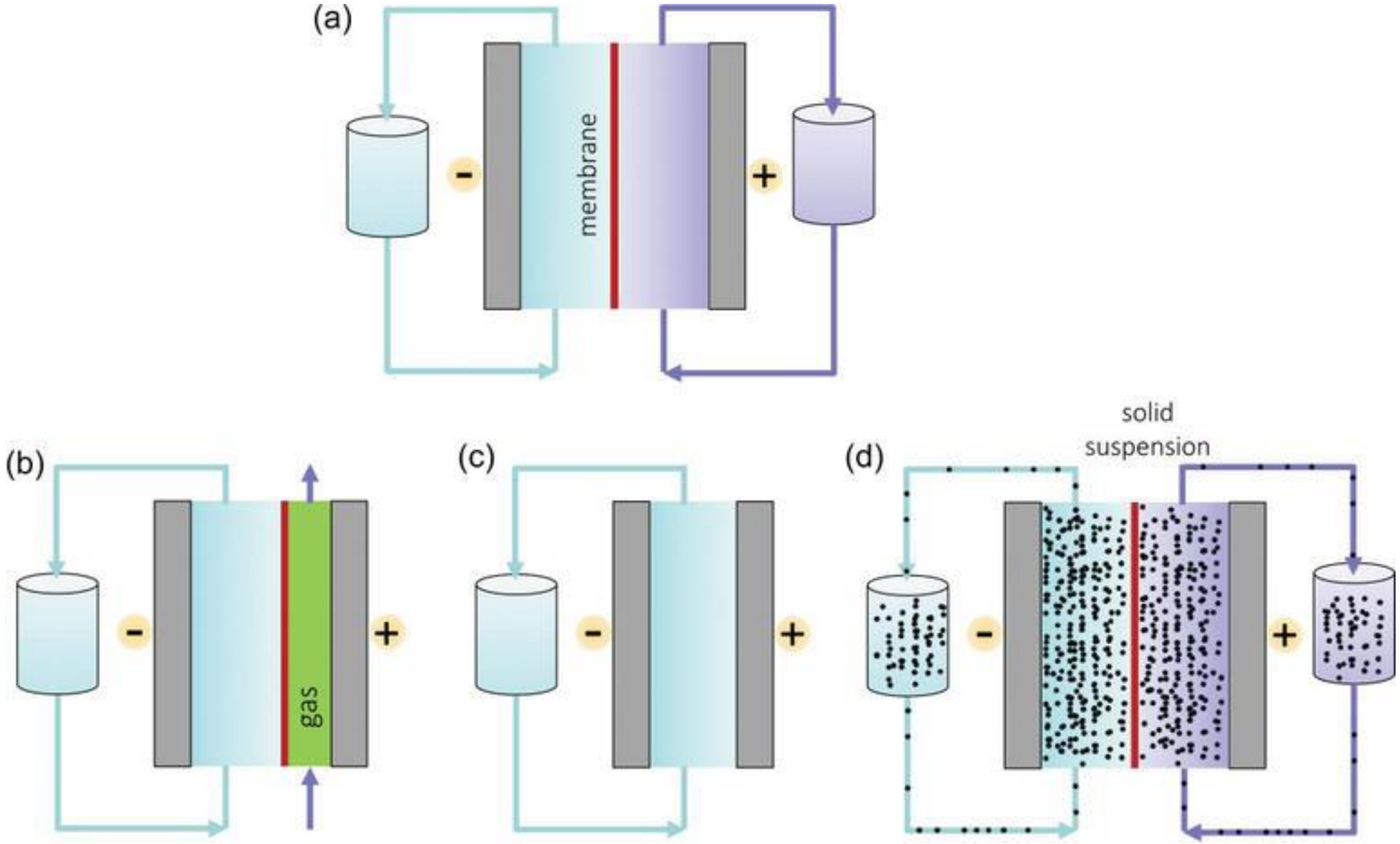
Fuente: https://en.wikipedia.org/wiki/List_of_battery_types

Baterías de Flujo

Redox flow battery: Working principle



TIPOS DE BATERÍAS DE FLUJO



Mirar en: https://www.intechopen.com/books/redox-principles-and-advanced-applications/redox-flow-batteries-fundamentals-and-applications

5 Top Flow Battery Startups Impacting the Energy Industry

startus INSIGHTS

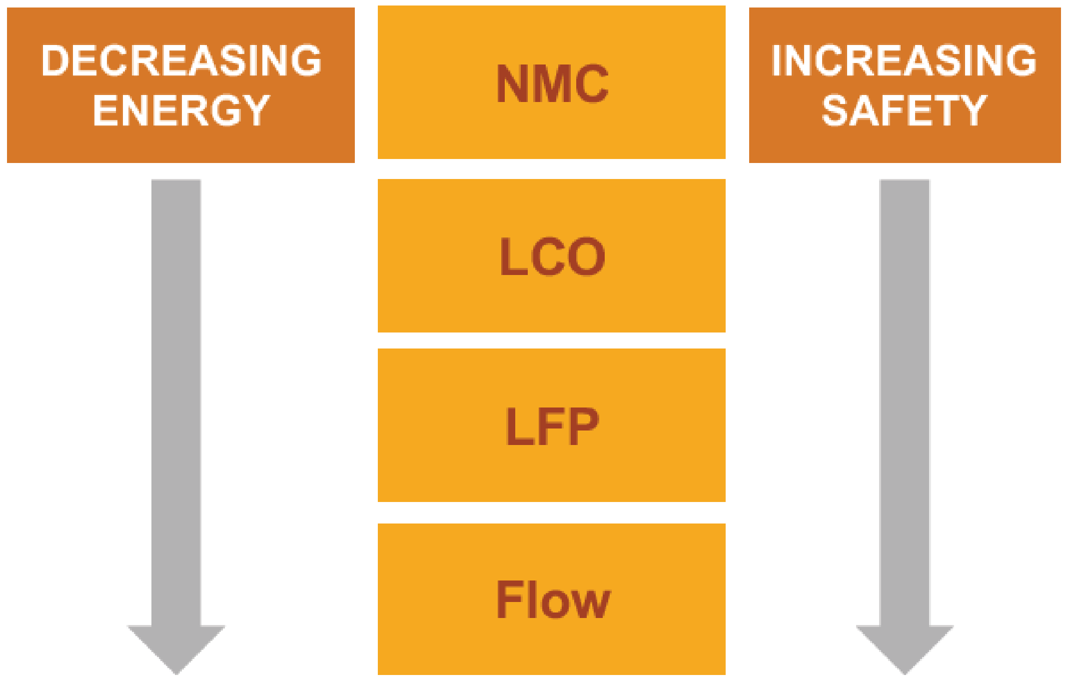
Mai 2019

This Heat Map illustrates the geographical distribution of 5 out of 124 flow battery startups disrupting the energy industry.

Chemistries - Lithium-Ion Family

Current Positive Electrodes

- **LiCoO2**
  Lithium Cobalt Oxide (LCO)
- **LiNiCoAlO2**
  Lithium Nickel Cobalt Aluminum (“NCA”)
- **LiNiMnCoO2**
  Lithium Nickel Manganese Cobalt ("NMC")
- **LiMn2O4**
  Lithium Manganese Oxide (LMO)
- **LiFePO4**
  Lithium Iron Phosphate ("LFP")



ELECTRO-QUÍMICO: BATERÍAS TIPOS

Secundarias

- Lithium metal battery
- Magnesium-ion battery
- Metal–air electrochemical cells
  - Lithium air battery
  - Aluminium–air battery
  - Germanium air battery
  - Calcium air battery
  - Iron air battery
  - Potassium-ion battery
  - Silicon–air battery
  - Zinc–air battery
  - Tin air battery
  - Sodium-air battery
  - Beryllium air battery

Secundarias

- Molten salt battery
- Microbial fuel cell
- **Nickel–cadmium battery**
  - Nickel–cadmium battery vented cell type
- Nickel hydrogen battery
- **Nickel–iron battery**
- **Nickel metal hydride battery**
  - Low self-discharge NiMH battery
- Nickel–zinc battery
- Organic radical battery
- Polymer-based battery
- Polysulfide bromide battery
- Potassium-ion battery

Fuente: https://en.wikipedia.org/wiki/List_of_battery_types

ELECTRO-QUÍMICO: BATERÍAS TIPOS

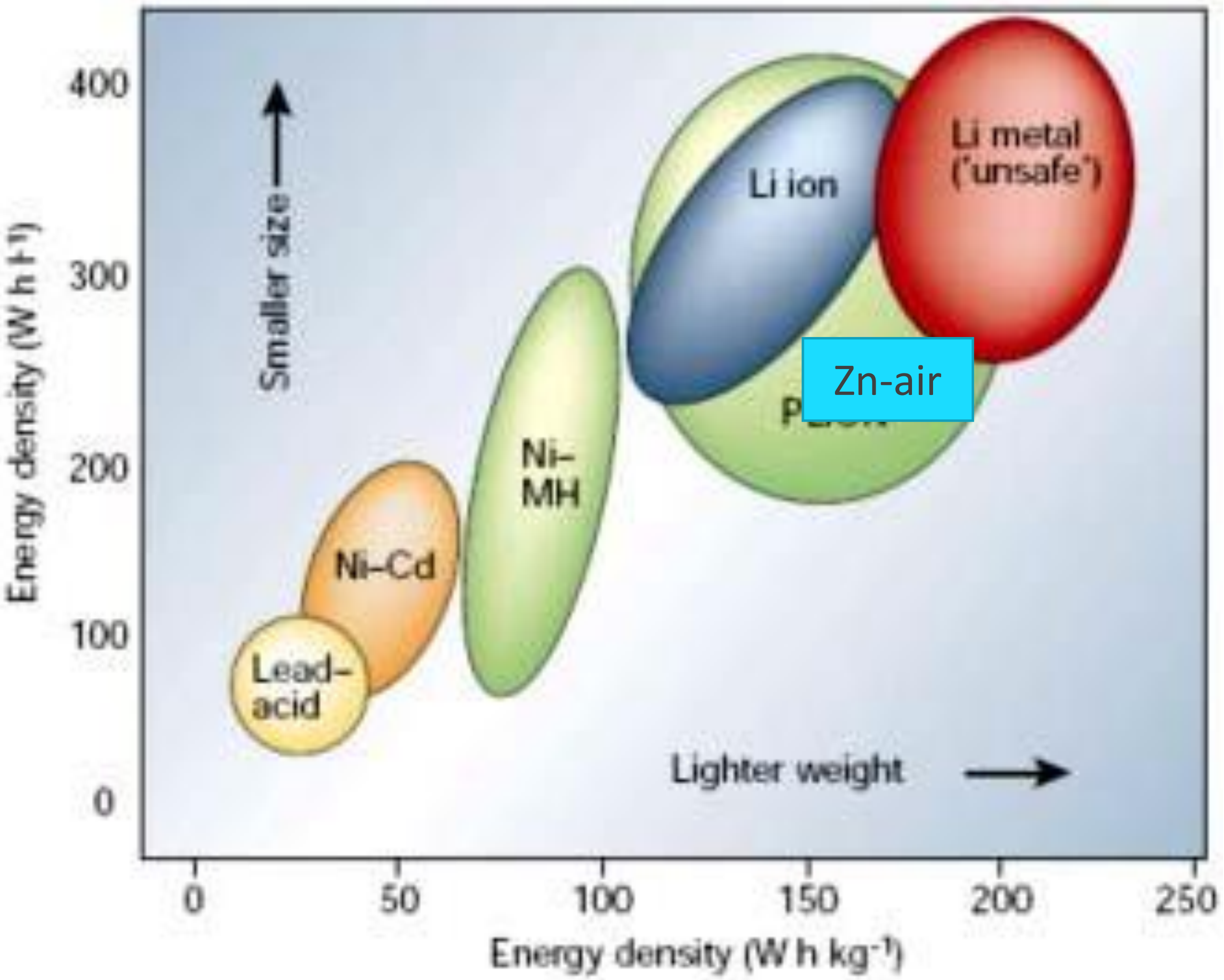
Secundarias

- Rechargeable alkaline battery
- Rechargeable fuel battery
- Sand battery
- Silicon air battery
- Silver-zinc battery
- Silver calcium battery
- Silver-cadmium battery
- Sodium-ion battery
- Sodium–sulfur battery
- Solid-state battery [4]
- Super iron battery
- UltraBattery
- Zinc ion battery

Fuente: https://en.wikipedia.org/wiki/List_of_battery_types

ELECTRO-QUÍMICO: BATERÍAS TIPOS MÁS COMUNES

- Plomo-acido (Pb-ácido) – 1859 /1970
- Nickel-cadmio (NiCd) – 1899 / 1947
- Nickel-hierro - 1901
- Nickel-hidruro metálico (NiMH) – 1990



¿CÓMO ESCOGER LA MEJOR BATERÍA?

1. Densidad energética
2. Densidad de potencia
3. Seguridad
4. Ciclo de vida
5. Costo

ELECTRO-QUÍMICO: COMPARACIÓN

Tipo	Energía/ peso	Tensión por elemento (V)	Duración (número de recargas)	Tiempo de carga	Auto-descarga por mes (% del total)
Plomo	30-50 Wh/kg	2 V	1000	8-16h	5 %
Ni-Cd	48-80 Wh/kg	1,25 V	500	10-14h *	30%
Ni-Mh	60-120 Wh/kg	1,25 V	1000	2h-4h *	20 %
Li-ion	110-160 Wh/kg	3,16 V	4000	2h-4h	25 %
Li-Po	100-130 Wh/kg	3,7 V	5000	1h-1,5h	10%

ELECTRO-QUÍMICO: RESUMENCITO

Familias de baterías recargables

Plomo-ácido (LA)

Ventajas: madurez tecnológica/bajo costo/fiabilidad y modularidad.

Desventajas: baja densidad energética/alta dependencia con la temperatura de operación/eficiencia.

Uso: UPS/maquinaria industrial/renovables/telecomunicaciones/Servicios auxiliares

Alcalinas (NiCd & NiMH)

Ventajas: madurez tecnológica/fiabilidad/elevados régimenes de carga y descarga/amplio rango de temperaturas de operación/bajo mantenimiento.

Desventajas: costo/autodescarga/efecto memoria/aspectos medioambientales.

Uso: maquinaria y vechículos industriales/portacables sector domésticos/tracción/renovables

Sales fundidas

Ventajas: eficiencia energética/modularidad y escalabilidad/no autodescarga/densidad energética.

Desventajas: largos periodos de precalentamiento/costo/necesidad de desarrollo/escasos fabricantes.

Uso: Almacenamiento estacionario gran escala/renovables/UPS/tracción

Litio-ion

Ventajas: Eficiencia energética/flexibilidad/baja autodescarga/densidad energética/tensión de celda/régimenes de carga y descarga/varios fabricantes.

Desventajas: seguridad/costo/protección.

Uso: Desde apliaciones de baja potencia a almacenamiento estacionario gran escala/sector residencial & industrial/vehículos.

Fuente: (Atienza Serna, 2011)

TIPOS DE HIDRÓGENO: ¡SUS COLORES!

Hidrógeno ROSADO

4% - 5% | 95% - **96%**

"COLOR"	VERDE	NEGRO/CAFÉ	GRIS (71%)	AZUL	TURQUESA
FUENTE PRIMARIA	Agua	Petróleo/**Carbón o lignita**	Gas Natural/**Carbón**	Gas Natural	Metano
PROCESO	Electrólisis + Generación por Fuentes Renovables *	Reforming o **Gasificación**	Reforming o **Gasificación**	Reforming	Pirólisis o Proceso Hazer
SALIDAS	Hidrógeno + Agua	Hidrógeno + CO_2	Hidrógeno + CO_2	Hidrógeno + CO_2	Hidrógeno + GRAFITO
EMISIONES	NO	**SÍ**	**SÍ**	SÍ + **CCS**	NO

SYNGAS

* Nuclear incluída.

ELECTROLIZADORES

Como una batería, tiene:

Ánodo y un cátodo separados por un electrolizador, o sea: **membrana**

PEM (proton exchange membrane)

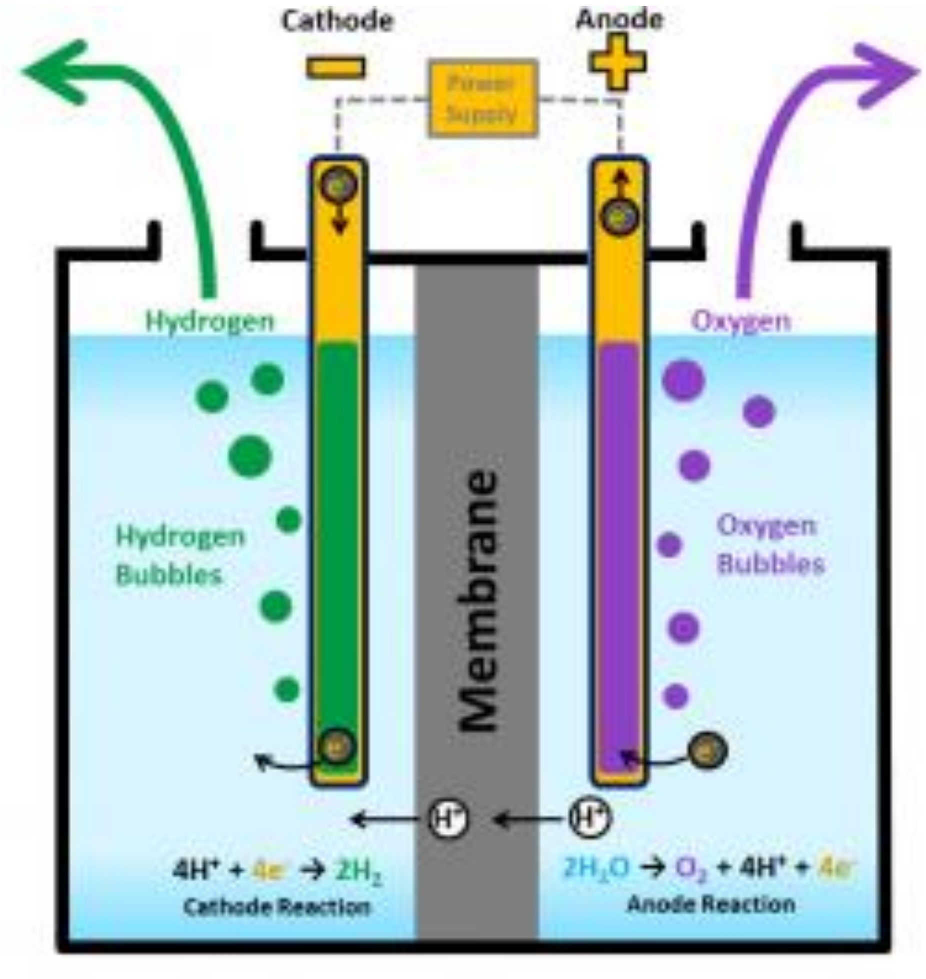
PEMEC (polymer electrolyte membrane) => P2Gas

Ánodo Rx: 2 H2O => O2 + 4H+ + 4e-

Cátodo Rx: 4H+ + 4e- => 2H2

Otros electrolyzers

- **Alcalinos (AEC):** soluciones liquidas alcalinas hidróxido de sodio o hidróxido de potasio. Acá se mueve OH- por la membrana del cátodo al ánodo **=> ER**
- Solid Oxide (SOEC): materiales cerámicos que conducen O-



ELECTROLYZER: PEM

POWER TO GAS (P2G)

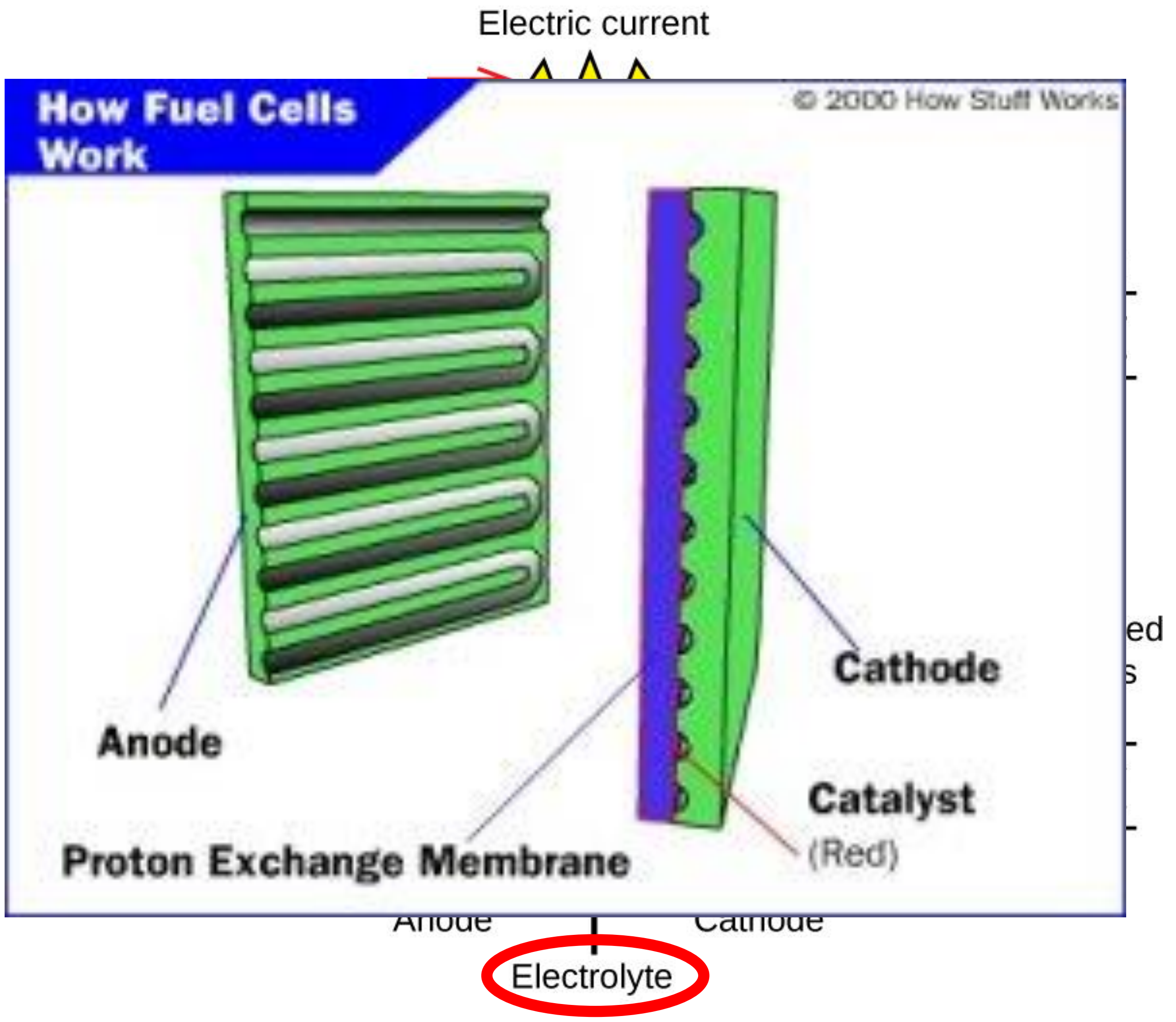
Producción de gas combustible con energía eléctrica: HIDRÓGENO o METANO

H2: electrólisis => P2G H2

Metano: biogás, gas, Metanización de aguas => P2G Metano

ELECTRO-QUÍMICO: CELDAS DE HIDRÓGENO

- PEMFC: polimer Exchange membrane FC
- SOFC: solid oxide FC
- AFC: alcaline FC
- MCFC: molten-carbonate FC
- PAFC: phosphoric acid FC
- DMFC: Direct methanol FC



Fuente: https://courses.lumenlearning.com/chemistryformajors/chapter/batteries-and-fuel-cells-2/

… Y EMPECEMOS CON LOS EJEMPLOS…

NORUEGA

With regard to high-temperature electrolysers, a pilot project in Norway produces synthetic fuel from hydrogen and CO2. The plant is to be scaled up to produce 8 kilotonnes of synthetic crude oil from 20 MW of input power.

$H_2 + N_2$ *(73% of air)* $\longrightarrow NH_3$

- Ammonia liquefies at **-33°C**
- 1 kg of liquid hydrogen carried in **9.5 litres**
- Ammonia production is already almost a third of hydrogen usage
- Mainly used for fertilizers
- Can consume **10-15%** of the energy content of the hydrogen (one-way)
- Supply chain exists

Refrigerated ammonia barge (image: Vigor)

Norwegian energy major Equinor to run ship fitted with ammonia fuel cells

PUBLISHED FRI, JAN 24 2020•4:28 AM EST

Source: www.cnbc.com/2020/01/24/equinor-to-run-ship-fitted-with-ammonia-fuel-cells.html

REINO UNIDO

ZeroAvia celebrates milestone

By Molly Burgess on Jun 23, 2020 | Translate NEWS

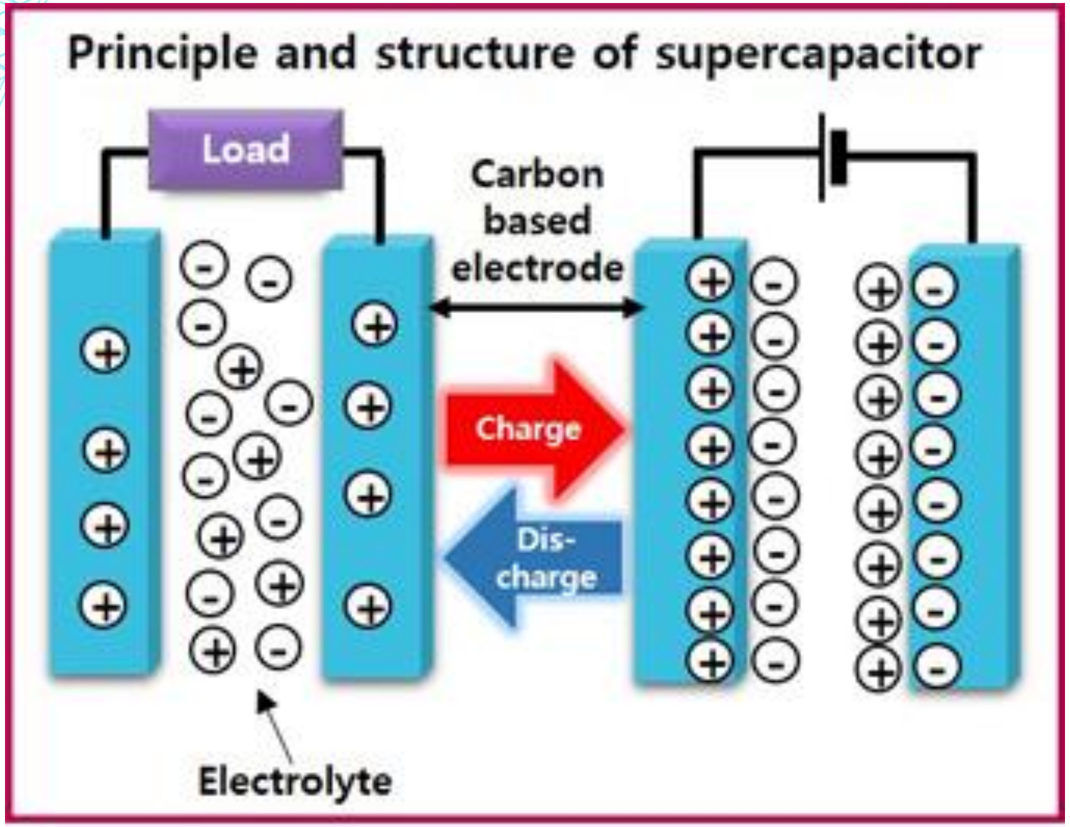
Hydrogen-focused powertrain developer ZeroAvia yesterday conducted the UK's first ever electric-powered flight of a commercial-scale aircraft, marking an important milestone in the UK Government funded project to develop hydrogen-electric powertrains.

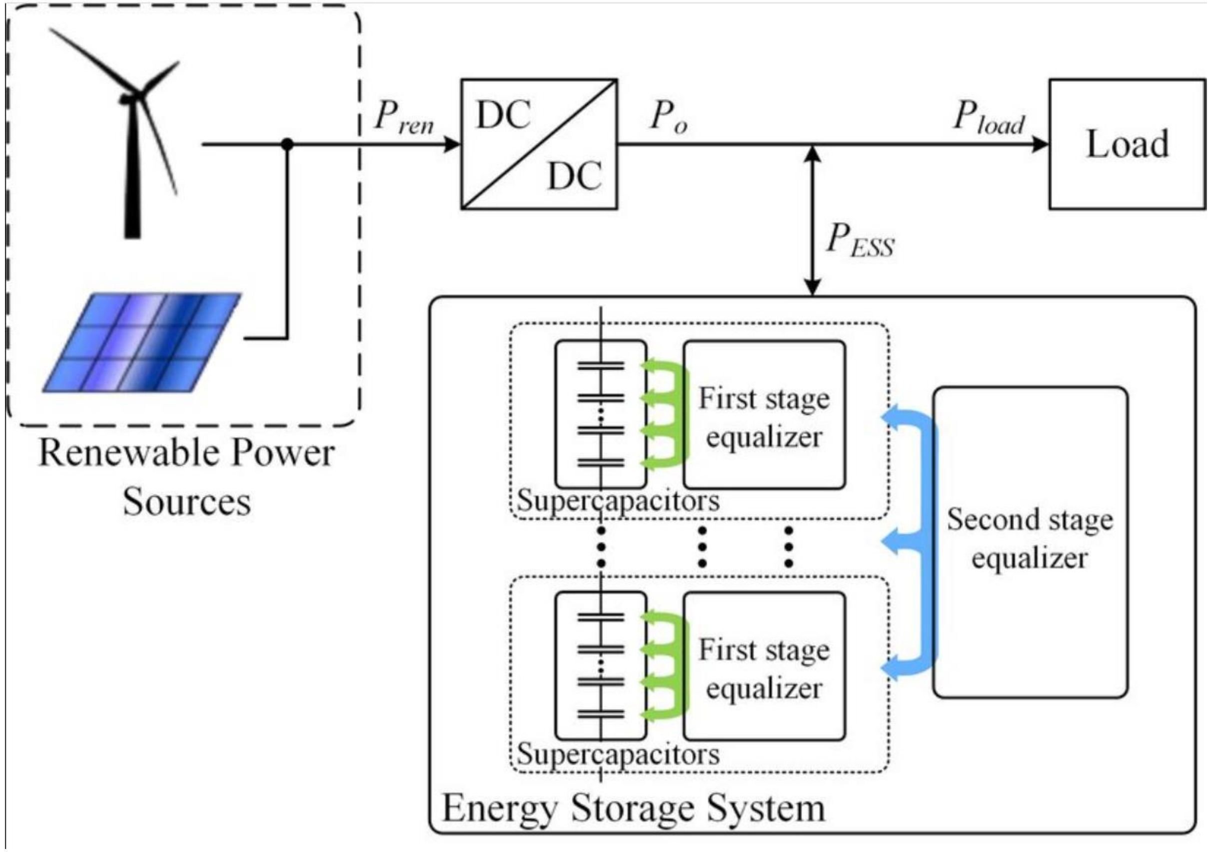
"Today's flight is the latest in a series of milestone that moves the possibility of zero emission flight closer to reality," said Val Miftakhov, ZeroAvia Founder and CEO.

"We all want the aviation industry to come back after the pandemic on a form footing to be able to move to a net zero future, with a green recovery."

"That will not be possible without realistic, commercial options for zero emission flight, something we will bring to market as early as 2023."

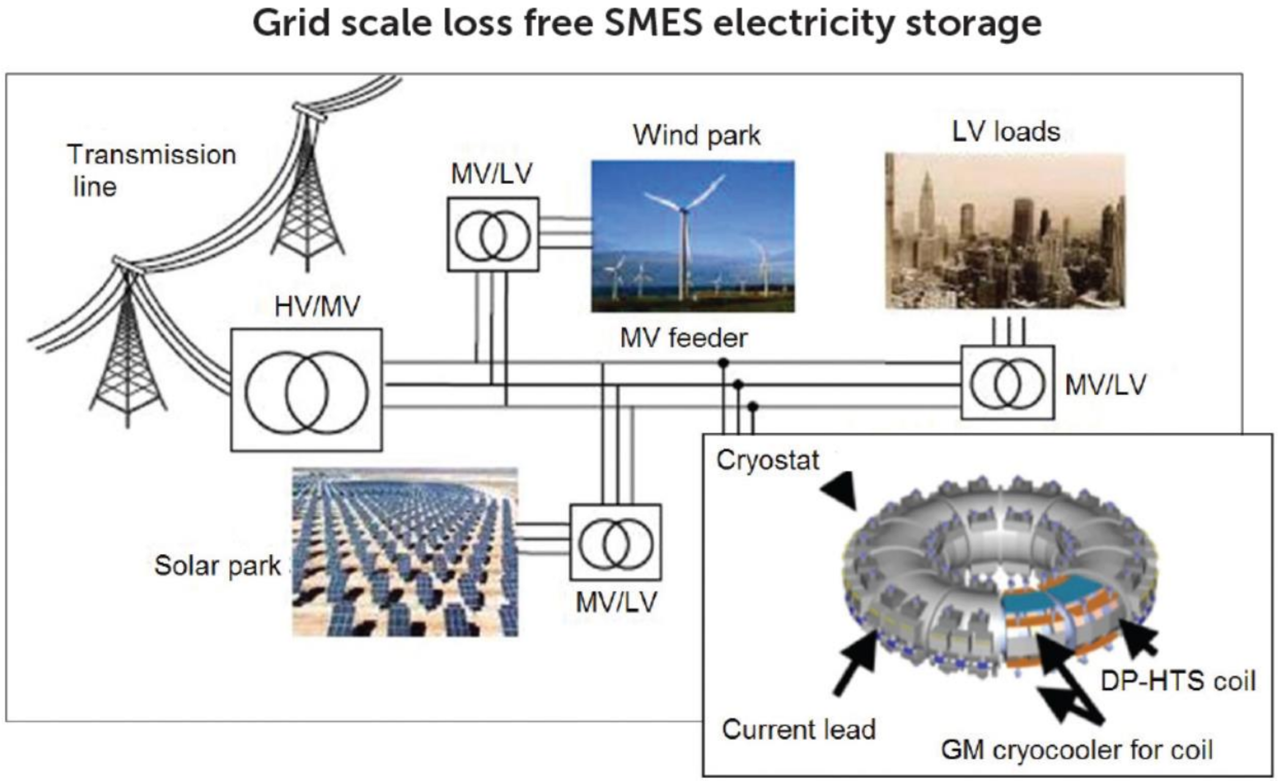
ELECTRO-QUÍMICO: SUPERCONDENSADORES O SUPERCAPACITORES





Fuente: https://cicusa.com/energy-storage-supercapacitors/

ELECTRO-MAGNÉTICA: BOBINA SUPRACONDUCTORA



ELECTRO-MAGNÉTICA: BOBINA SUPRACONDUCTORA

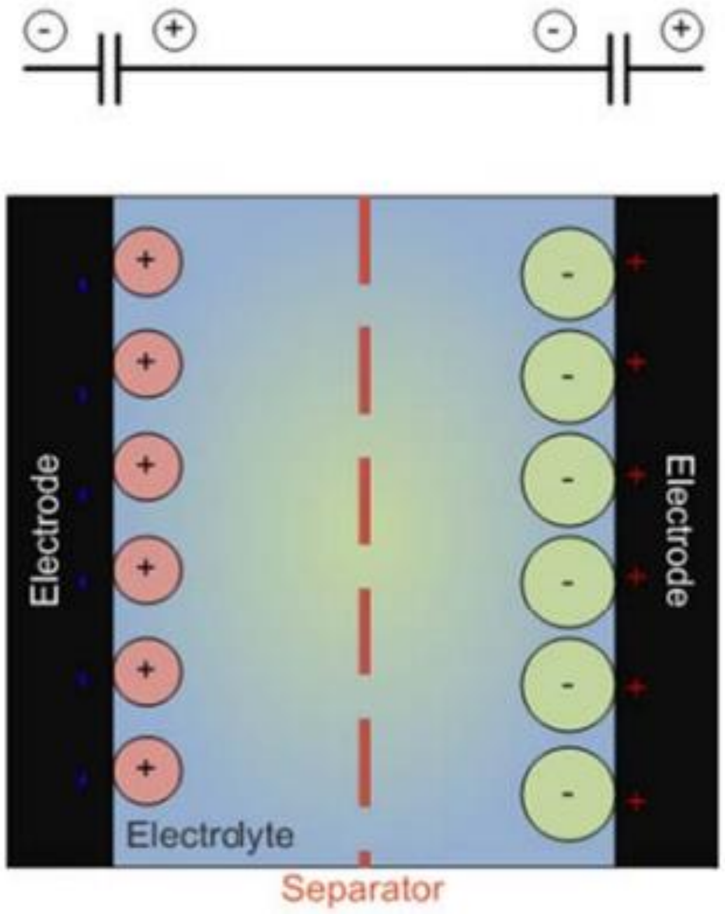
Table 1: SMES projects around the world. Data taken from [33]

Superconductor Material	Storage size (MJ)	Application	Country	Year
NbTi	30	Low frequency damping	USA	1980
	100			2003
	1	UPS	Japan	2006
	20	Instantaneous Voltage drop compensation		2004
	2.9	Power System Stability	China	2006
	2	Impulse Power Source		2010
	2.6	Sensitive load protection	Italy	2006
Bi 2212	1	Voltage drop protection	Japan	2009
	0.8	Impulse Power Source	France	2005
Bi 2223	0.15	UPS	Germany	2003
YBCO	2400	Load Fluctuation Compensation	Japan	2010

Se usan porque:

1. Tienen respuesta rápida y pueden entregar mucha energía
2. Pueden switchearse de carga a descarga(viceversa) en segundos.
3. No tiene partes móviles y tienen una alta eficiencia (la energía que le doy y la que me entrega)
4. Es útil en zonas donde poner baterías o aire comprimido no es factible

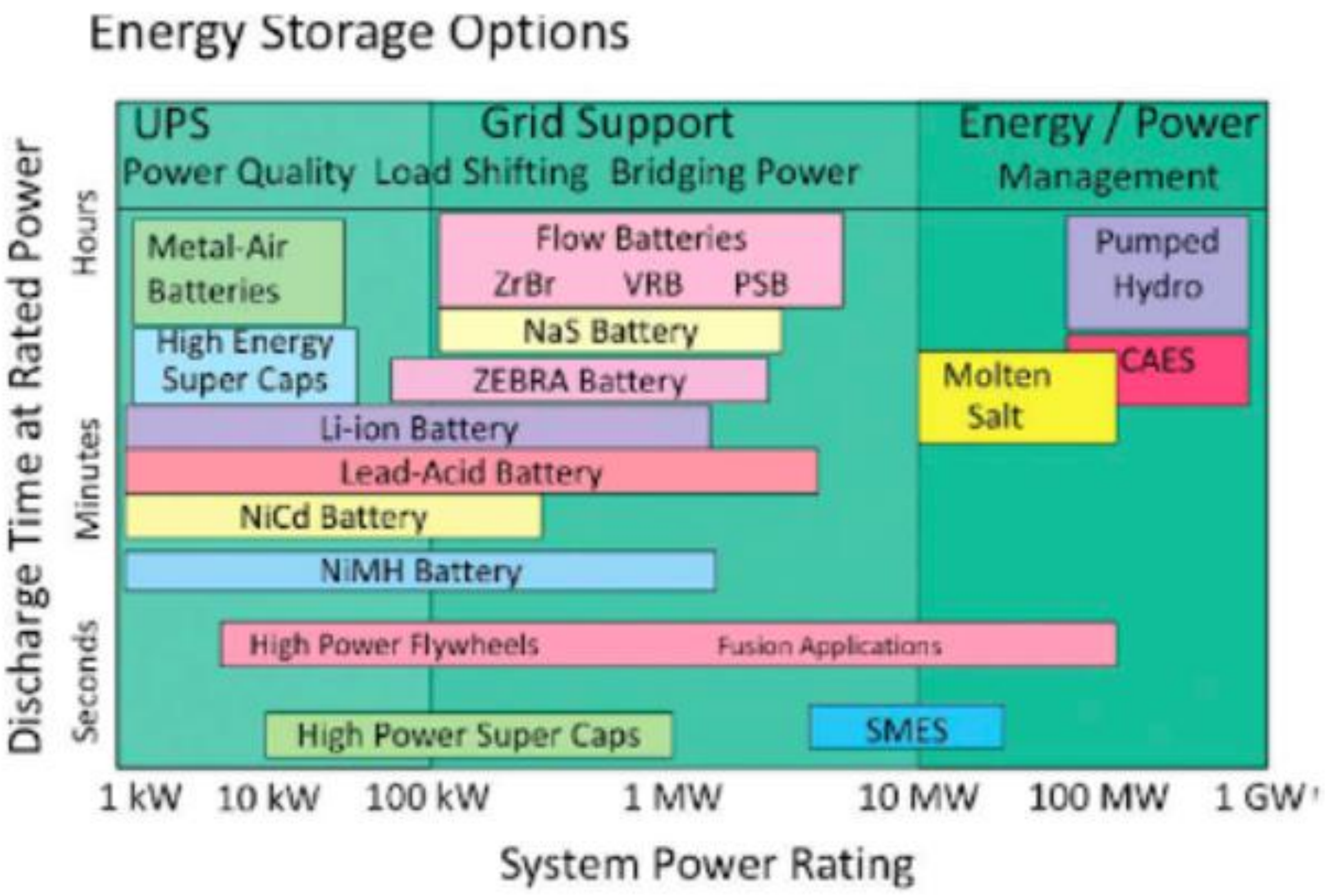
ELÉCTRICA: CONDENSADORES O CAPACITORES



Siemens, Sitars ESM 125 Water Cooled Energy Storage Module

Key Specifications:
Rated Voltage: 120 ... 125 V d.c.
Rated Capacitance: 63 F
Usable Energy Storage: 105 Wh
Usable Current Range: 150 ... 170 A d.c.
Maximum Series Module: 8
Operational Cycles: 1,000,000

RESUMEN…


Energy Storage Options
UPS
Power Quality
Grid Support
Load Shifting
Bridging Power
Energy / Power
Management
Hours
Minutes
Seconds
Metal-Air Batteries
Flow Batteries
ZrBr VRB PSB
Pumped Hydro
NaS Battery
High Energy Super Caps
ZEBRA Battery
CAES
Molten Salt
Li-ion Battery
Lead-Acid Battery
NiCd Battery
NiMH Battery
High Power Flywheels
Fusion Applications
High Power Super Caps
SMES
Discharge Time at Rated Power
1 kW
10 kW
100 kW
1 MW
10 MW
100 MW
1 GW
System Power Rating

Sistemas de Almacenamiento de Energía: Tecnologías

Storage Technology	Main applications	Strengths	Weaknesses
Pumped Hydro Power	Frequency control (secondary reserve, minute reserve), Voltage control, Peak shaving, Load leveling, Standing reserve, Black start	Established technology, Very long life-time, Low self-discharge, Good efficiency, Low energy installation costs	Environmental concerns, Low energy density (large footprint), Geographical restriction, High investment costs, Long return of investment (> 30 years), Only large units connected to the transmission grid are economical
Compressed Air Energy Storage System	Frequency control, Voltage control, Peak shaving, Load leveling, Standing reserve, Black start	Relatively low cost for the energy storage (caverns), Small footprint on surface due to underground storage, Long life of the air reservoir (cavern) and the power systems (compressors, turbine), Low self-discharge of compressed air	Certain geological restrictions necessary (pressure-tight cavern), High investment costs, Only two (and old) diabatic pilot plants, no adiabatic power plants available yet, Thermal storage for adiabatic CAES not yet demonstrated in full scale, High self-discharge of the thermal storage, Low efficiency for diabatic CAES (< 55%), Long return of investment (> 30 years), Only large units connected to the transmission grid are economical
Flywheel	Primary frequency control, voltage control, Peak shaving, UPS	Fast charge capability, No capacity degradation, Low maintenance requirements, Long life time, Better composite materials may allow higher rotational speed and therefore increased energy density	Low energy density, Vacuum chamber needed, Safety reasons; crack occur due to dynamic loads, bearing failure on the supports, external shocks, Cooling system for superconducting bearings, Very high self-discharge
Super-Capacitor	Primary frequency control, voltage control, Peak shaving, UPS	High efficiency, High power capability, Long cycle lifetime	Low energy density, High costs per installed energy
Flow Batteries	Secondary/Tertiary frequency control, Long-term storage, Island grids	Energy and power independently scalable, High cycle life, Variety of battery chemistries possible	Leakage caused by acidic fluids, Life of cell stack is limited, Costs for vanadium-based redox solution is too high, Pumps and valves are prone to errors and costly maintenance, Supply chain, Maturity level, Low efficiency and density, Legal approval problems for large systems with large amounts of acid, environmental risks.
Lithium Ion Batteries	Frequency control, Voltage control, Peak shaving, Load leveling, Electromobility, Residential storage systems	High energy density, Long lifetime, High performance, Supply chain, Cost reduction trend going down	No inherent security (thermal runaway), Sophisticated battery management system required (single cell monitoring), Packaging and cooling costly depending on cell shape, High costs
Lead Acid Batteries	Frequency control, Peak shaving, Load leveling, Island grids, Residential storage systems, Uninterruptible power supply	Today already high number of installations, Acceptable energy and power density for stationary applications, Inherent safety by controlled overcharge reaction, No complex cell management needed, Good temperature performance, Experience with large storage, Short amortization period and relatively low initial investment, Mature technology, Established recycling and high recovery rate of materials	Charging and discharging ability are not symmetrical (charging is slower than discharge), Ventilation required, Restrictions to the location of the battery system, Limited life cycle, Industrial batteries are still not built with fully automatic systems, Low efficiency, energy density and depth of discharge
Sodium Sulfur Batteries	Frequency control, Peak shaving, Load leveling, Island grids, Electromobility (Zebra), Uninterruptible power supply	High specific energy, High cycle and calendar lifetime, Cheap raw materials (NaS), Many stationary plants existing (NaS)	High thermal standby losses, Hazard potential due to high operating temperature, High cost for Nickel-material, Supply chain

(ISEA, 2012)

		Selected Advantages	Selected Disadvantages
Mechanical/Gravity/Thermal	Compressed Air	• Low cost, flexible sizing, relatively large scale • Mature technology and well-developed design • Proven track record of safe operation • Leverages existing gas turbine technologies	• Requires suitable geology • Relatively difficult to modularize for smaller installations • Exposure to natural gas price changes • Relies on natural gas
	Flywheel	• High power density and scalability for short-duration technology; low power, higher energy for long-duration technology • High depth of discharge capability • Compact design with integrated AC motor	• Relatively low energy capacity • High heat generation • Sensitive to vibrations
	Pumped Hydro	• Mature technology (commercially available; leverages existing hydropower technology) • High-power capacity solution • Large scale, easily scalable in power rating	• Relatively low energy density • Limited available sites (i.e., water availability required) • Cycling generally limited to once per day
	Thermal	• Low cost, flexible sizing, relatively large scale • Power and energy ratings independently scalable • Leverages mature industrial cryogenic technology base; can utilize waste industrial heat to improve efficiency	• Technology is pre-commercial • Difficult to modularize for smaller installations • On-site safely concerns from cryogenic storage
Chemical	Flow Battery‡	• Power and energy profiles independently scalable for vanadium system • Zinc bromide designed in fixed modular blocks for system design • No degradation in "energy storage capacity" • No potential for fire • High cycle/lifespan	• Power and energy rating scaled in a fixed manner for zinc bromide technology • Electrolyte based on acid • Relatively high balance of system costs • Reduced efficiency due to rapid charge/discharge
	Lead Acid‡	• Mature technology with established recycling infrastructure • Advanced lead-acid technologies leverage existing technologies • Low cost	• Poor ability to operate in a partially charged state • Relatively poor depth of discharge and short lifespan • Acid-based electrolyte
	Lithium-Ion‡	• Multiple chemistries available • Rapidly expanding manufacturing base leading to cost reductions • Efficient power and energy density • Cost reduction continues	• Cycle life limited, especially in harsh conditions • Safety issues from overheating • Requires advanced manufacturing capabilities to achieve high performance
	Sodium‡	• High temperature technology: Relatively mature technology (commercially available); high energy capacity and long duration • Low temperature technology: Smaller scale design; emerging technology and low-cost potential; safer	• Although mature, inherently higher costs—low temperature batteries currently have a higher cost with lower efficiency • Potential flammability issues for high-temperature batteries • Poor cycling capability
	Zinc‡	• Deep discharge capability • Designed for long life • Designed for safe operation	• Currently unproven commercially • Lower efficiency • Poor cycling/rate of charge/discharge

Fuente: Lazard's Levelized Cost Of Storage Analysis—version 4.0_2018

Función de los BESS en el sistema eléctrico

BESS EN EL SECTOR ELÉCTRICO

SERVICIOS PARA EL SISTEMA DE POTENCIA

- Desplazamiento de carga – Curva Diaria -
- Suministro de capacidad

SERVICIOS COMPLEMENTARIOS

- Regulación de frecuencia
- Reserva rodante, fría y suplementaria
- Control de voltaje
- Arranque en negro
- Otros servicios relacionados (ERNC)

SERVICIOS A LA INFRAESTRUCTURA DE TRANSMISIÓN

- Diferir expansión de transmisión
- Aliviar congestiones en transmisión

SERVICIOS PARA INFRAESTRUCTURA DE DISTRIBUCIÓN

- Diferir expansión en distribución
- Soporte de voltaje

SERVICIOS DE GESTIÓN DE DEMANDA DEL USUARIO

- Calidad de potencia
- Confiabilidad potencia
- Desplazamiento de carga usuario final
- Control de demanda pico

*Fuente: **DOE/EPRI 2013 Electricity Storage Handbook – SANDIA - NRECA**

Ejemplos de sistemas de almacenamiento en el mundo

Proyectos recientes – Sistemas de potencia

Owner	Project Name	Power/Energy Rating	Service Description	Location	Year
AES Energy Storage	Alamitos Energy Storage Array	100 MW/ 400 MWh	AES was awarded a 20 yr PPA by SCE to provide local system capacity to ensure power system reliability in Western LA Basin.	Long Beach, CA	2021
AES Energy Storage	Tait Battery Array	40 MW/ n/a	Provide frequency regulation service to PJM, located at Dayton Power &Light's Tait generation station	Morraine, OH	2013
Invenergy	Grand Ridge Energy Storage	31.5 MW/12.2 MWh	First of Invenergy's twin projects to provide frequency regulation service in PJM	Marseiles, IL	2015
RES Americas	Jake Energy Storage Center	19.8 MW/7.8 MWh	Second of RES America's twin projects it provide frequency regulation service in PJM	Joliet, IL	2015
NextEra Energy	Frontier Energy Storage System	20 MW / n/a	Located at Lee/DeKalb Wind Energy Center in IL, provides freqeuncy regulation service in PJM	Lee/DeKalb	2015
SCE	**Tehachapi Wind Energy**	**8 MW/32 MWh**	**Will evaluate the performance of BESS to improve grid performance and assist in the integration of large-scale wind generation. (SCE and DOE)**	**Tehachapi, CA**	**2014**
Sempra	Auwahi Wind Farm	11 MW/4.4 MWh	Performs wind ramp rate management for a 21 MW wind farm located on the island of Maui.	Kula, HI	2012
Duke Energy	NoTrees Wind Storage	36 MW/24 MWh	Demonstration project by DOE ARRA grant and Duke Energy. Services include wind firming, frequency regulation and voltage support.	Goldsmith, TX	2012
SCE	Aliso Canyon Energy Storage	20MW/80MWh	CAISO market for day ahead and real time dispatch	Mira Loma, CA	2016

Sistemas de Almacenamiento de Energía: Instalaciones LATAM

Instalación	País	Tecnología	Potencia/ Capacidad	Servicios
Pedreira Pumped Hydro Power Station	Brazil	Open-loop Pumped Hydro Storage	20MW/-	Electric Energy Time Shift, Electric Supply Capacity
Los Reyunos Pumped Hydro Storage	Argentina	Open-loop Pumped Hydro Storage	224MW/-	Electric Energy Time Shift, Electric Supply Capacity
Rio Grande-Cerro Pelado Hydroelectric Complex	Argentina	Open-loop Pumped Hydro Storage	750MW/-	Electric Energy Time Shift, Electric Supply Reserve Capacity - Spinning
Auxiliar Maitenes Hydro Power Plant	Chile	Open-loop Pumped Hydro Storage	30.8MW/-	Electric Energy Time Shift, Electric Supply Capacity
Atacama I	Chile	Molten Salt Thermal Storage	12MW/4MWh	Electric Supply Reserve Capacity - Spinning, Renewables Capacity Firming, Renewables Energy Time Shift
Planta Solar Cerro Dominador	Chile	Molten Salt Thermal Storage	110MW/1925MWh	Onsite Renewable Generation Shifting
Minera El Tesoro CSP Installation	Chile	Heat Thermal Storage	10.5MW/68.25MWh	Renewables Capacity Firming, Renewables Energy Time Shift
Los Andes Substation Battery Energy Storage System - AES Gener	Chile	Lithium-ion Battery	12MW/4MWh	Electric Supply Reserve Capacity - Spinning, Frequency Regulation
AES Angamos Storage Array	Chile	Lithium-ion Battery	20MW/5MWh	Electric Supply Reserve Capacity - Spinning, Frequency Regulation

(Department of Energy (DOE) global database of energy storage projects .)

PREGUNTAS