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Batteries for Ham Radio

OUTLINE

- What is a battery?
- History of the battery
- Energy Density and Cost/kWh Versus Time
- $LiFePO_4$ (LFP) vs LiFo (Lithium Polymer) batteries
- POTA/SOTA Scenario A: QRP, Scenario B: 100W
- Portable Power Stations
- Solar Power and Batteries – Solar Charge Controllers
- What to look for in a battery/battery pack for ham radio
- Battery Safety
- $LiFePO_4$ Optimization Tips
- The future of batteries

What is a Battery?

- "A self-contained, chemical power pack that can produce a limited amount of electrical energy when needed"
- "A source of electric power consisting of one or more electrochemical cells with external connections for powering electrical devices"
- "A mechanism designed to store chemical energy and convert it to electrical energy, comprised of two electrodes separated by an electrolyte that produces direct current.

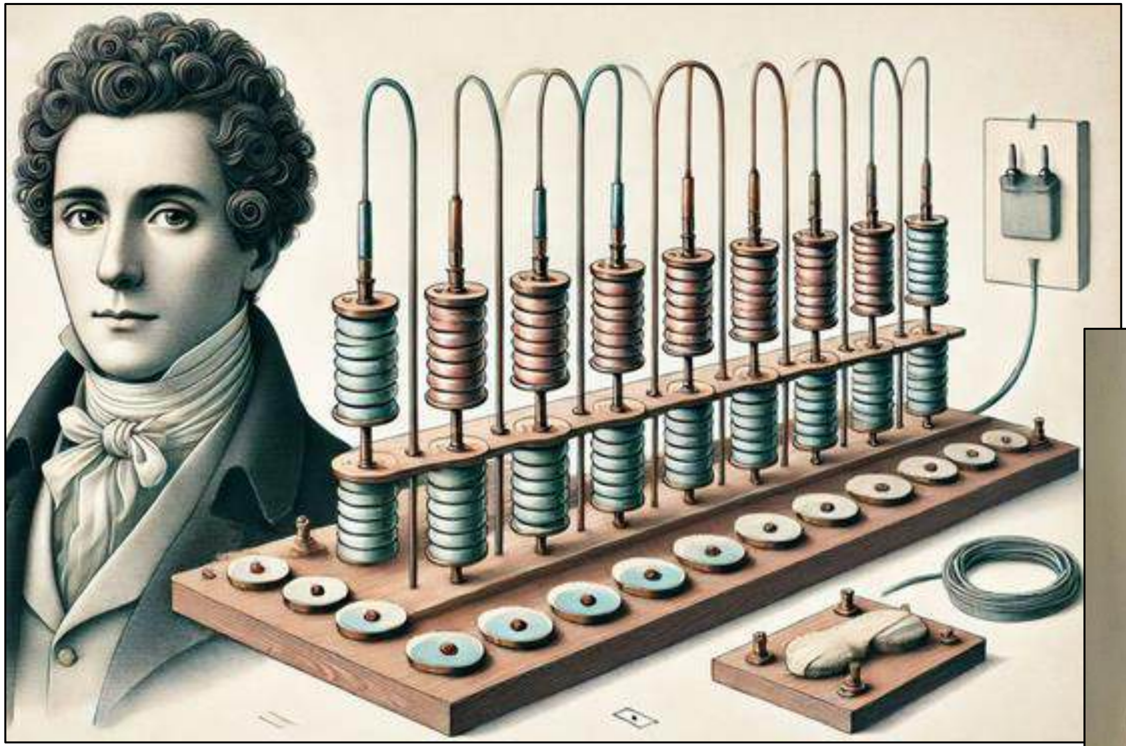
Common to each definition is the conversion of stored chemical energy to electrical energy than can power external electrical devices.

History of the Battery

- **1749** – Benjamin Franklin coined the term “battery” while doing experiment that linked Leyden jar capacitors, using the term for military weapons functioning together. The more jars, the more energy that could be stored and later used.

History of the Battery

- **1800** – Alessandro Volta built the “Voltaic pile” wet cell, consisting of a stack of copper and zinc plates separated by brine-soaked paper disks. It produced a steady electrical current for a length of time.



History of the Battery

- **1836** – John Daniell invented the **first modern storage cell**, consisting of two electrolytes: copper sulfate and zinc sulfate. It produced 1.1 volts and powered objects such as telegraphs, telephones and doorbells for over 100 years.

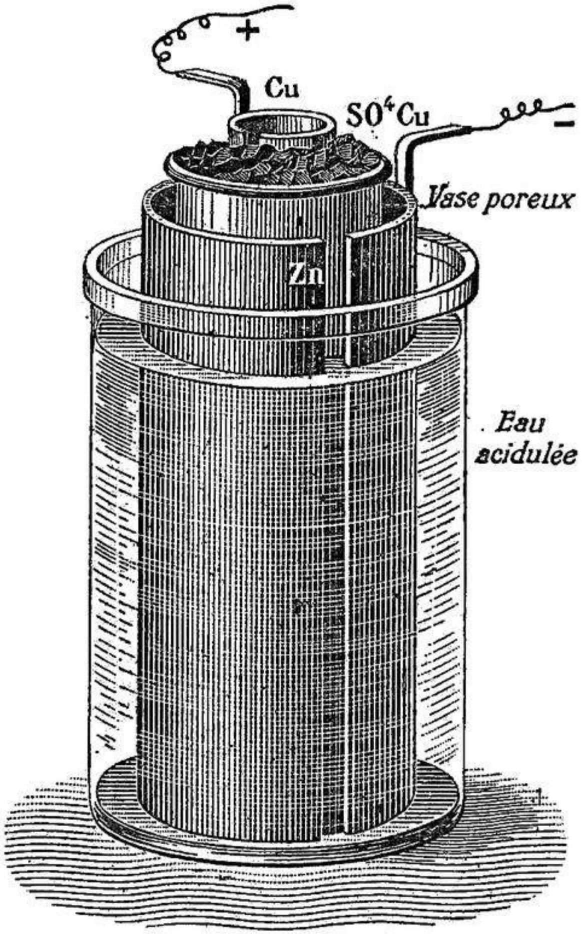


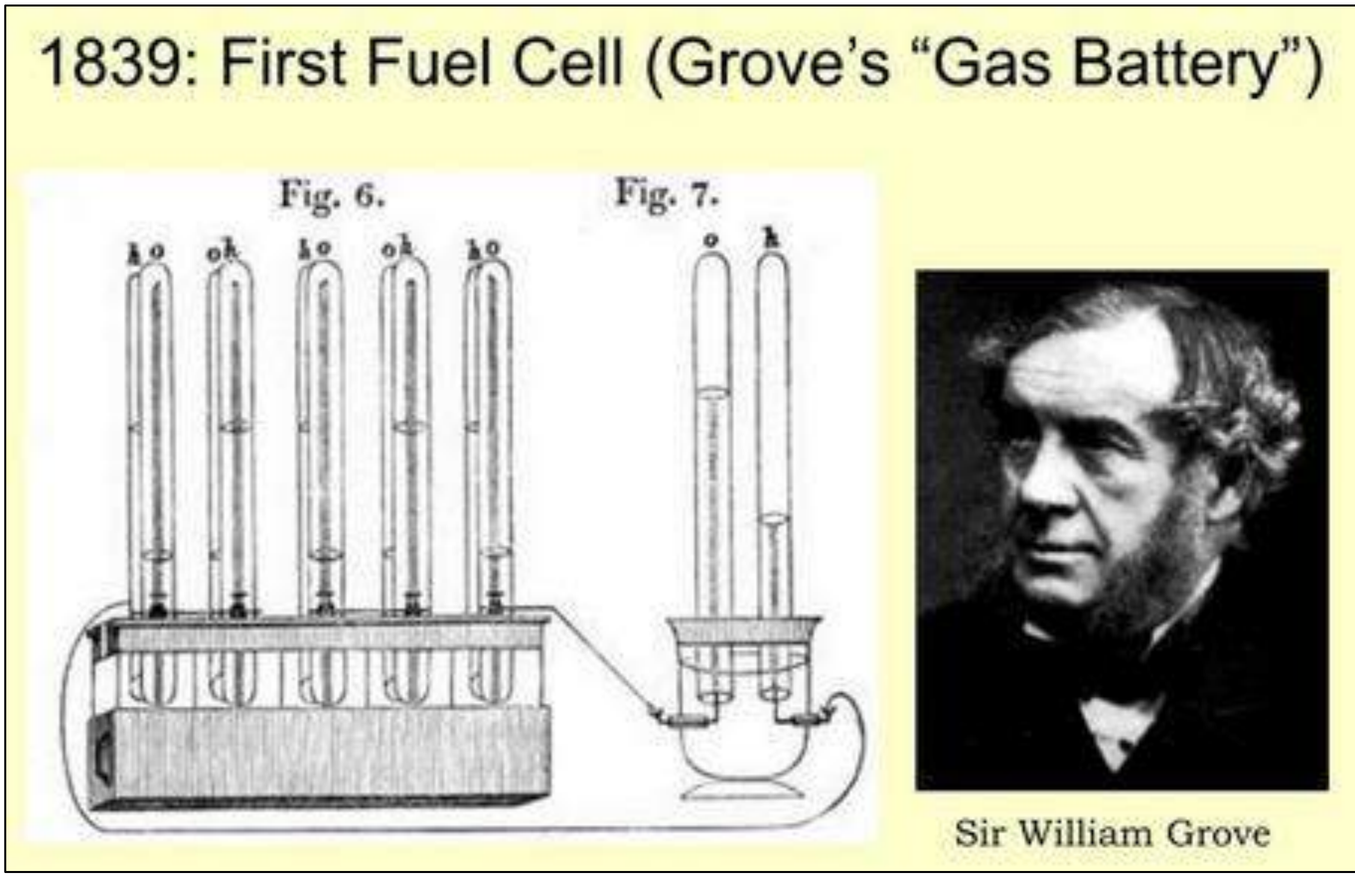
Fig. 284. — Élément Daniell.

Daniell cell (also known as a Crow's Foot or Gravity cell.)

A glass jar contains a copper star-shaped electrode in the bottom and a zinc "crow's foot" shaped electrode suspended near the top. The bottom of the jar was filled with a concentrated copper sulfate solution. On top of this was poured dilute sulfuric acid, whose lower density kept it on top.

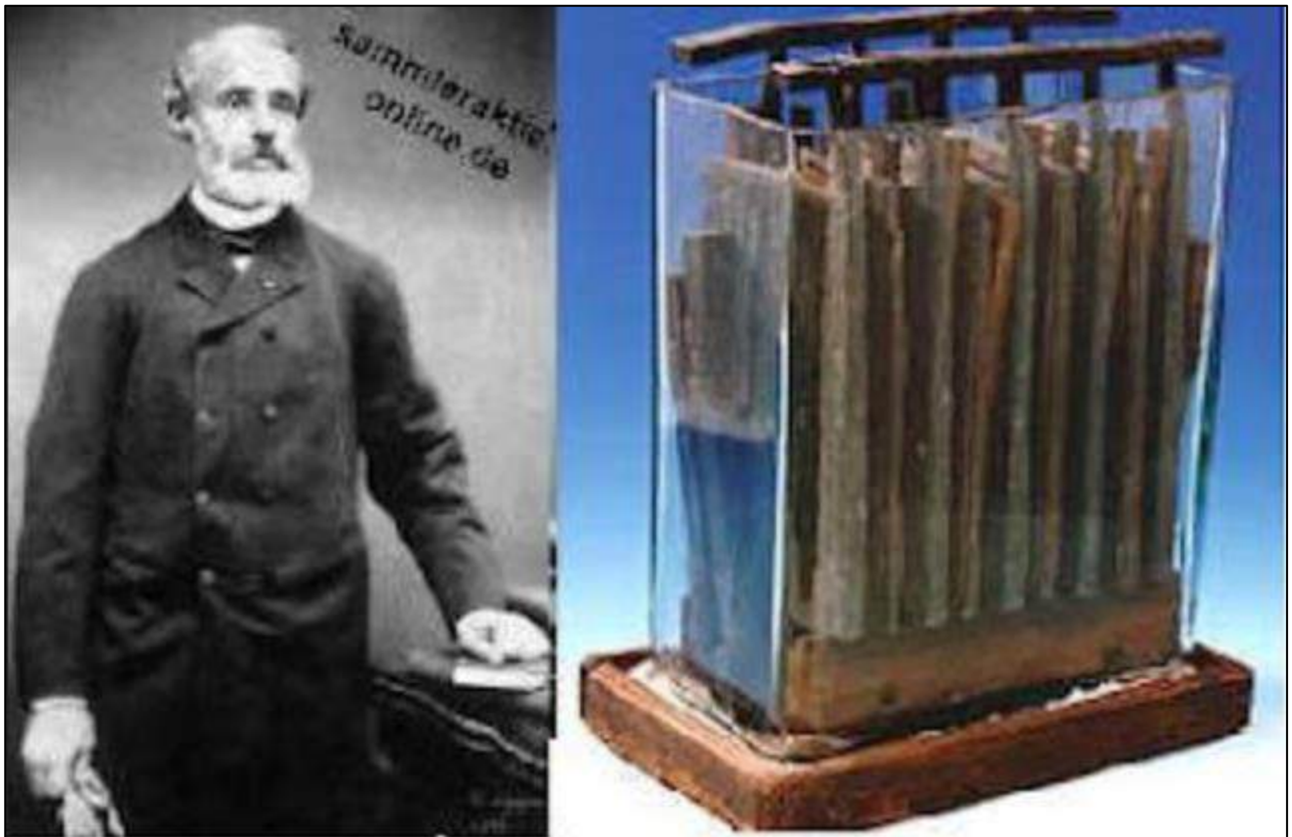
History of the Battery

- **1839** – William Grove developed the first “fuel cell” which combined hydrogen and oxygen to produce electricity (reverse electrolysis)



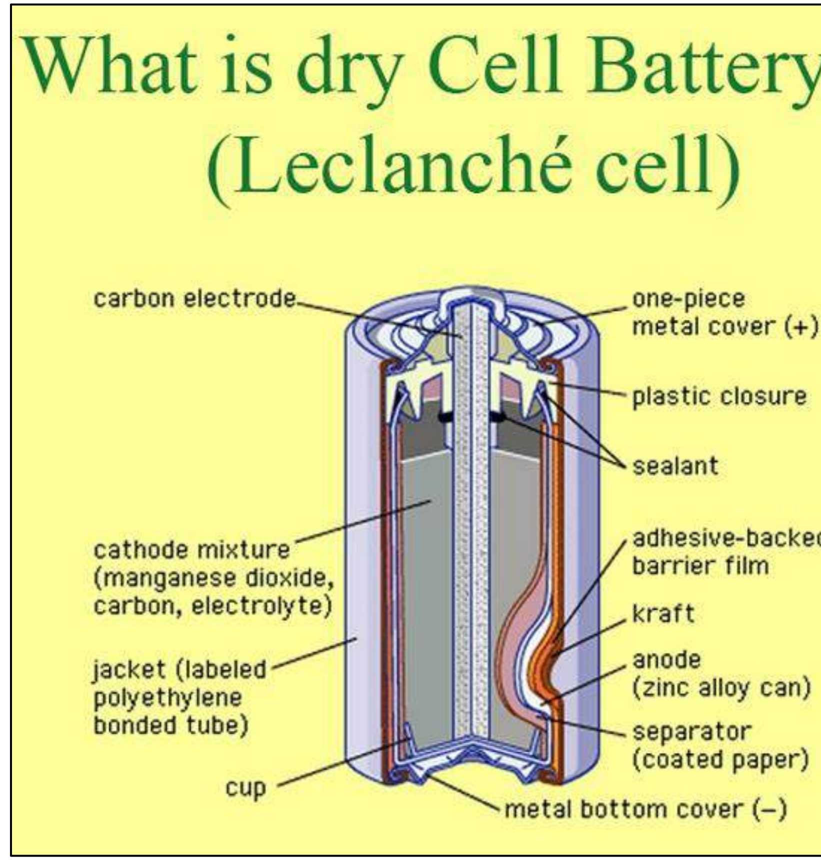
History of the Battery

- **1859** – Gaston Plante invented the first rechargeable lead-acid battery that could be recharged by a secondary battery. This type of battery is primarily used in cars today.



History of the Battery

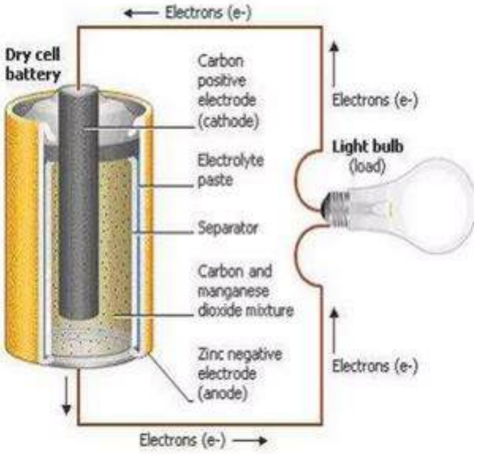
- **1866** – Georges Leclanché patented the carbon-zinc wet cell battery which led to the first dry cell through a series of improvements.



History of the Battery

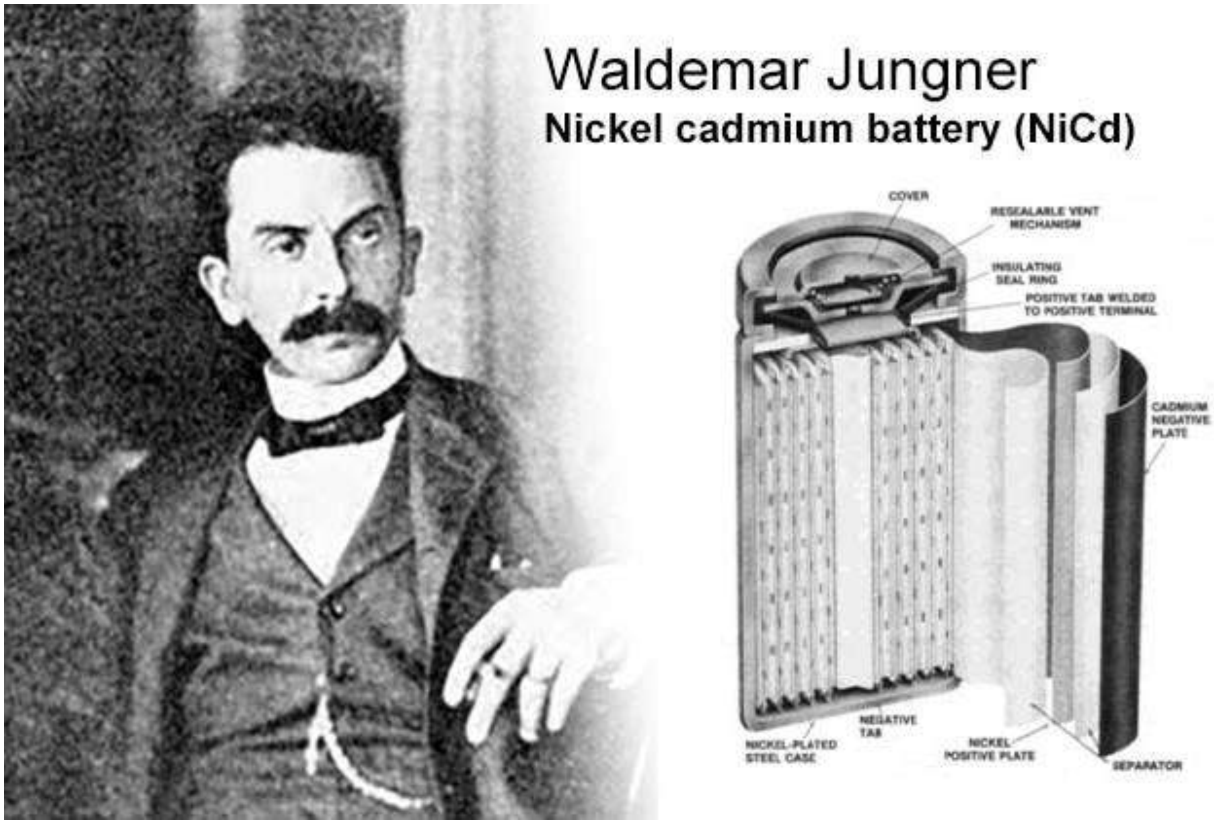
The first commercially successful dry cell battery (zinc-carbon cell).

- Invented in 1888 by Carl Gassner.
- It has three components negative electrode (zinc chloride ,ammonium chloride), positive electrode(carbon) and solution.
- When we connect the wires on both rods the electrons will moves from zinc rod to carbon rod (electric current will flow).
- Dry cells are used in flash lights, hand-held video games devices, cameras and clocks.



History of the Battery

- **1899 –** Waldmar Jungner invented the first nickel-cadmium rechargeable battery



- Cadmium forms the negative pole, and nickel forms the positive pole.
- Space between poles filled with KOH
- Made air-tight to prevent leakage and corrosion

Each cell produced about 1.2V and typical recharging time ~10 – 12 hours with low, steady current (what we'd now call *C/10 rate*, where C is battery's rated capacity in Ah)

History of the Battery

- **1901** – T.A. Edison invented the alkaline storage battery (NiFe cell)

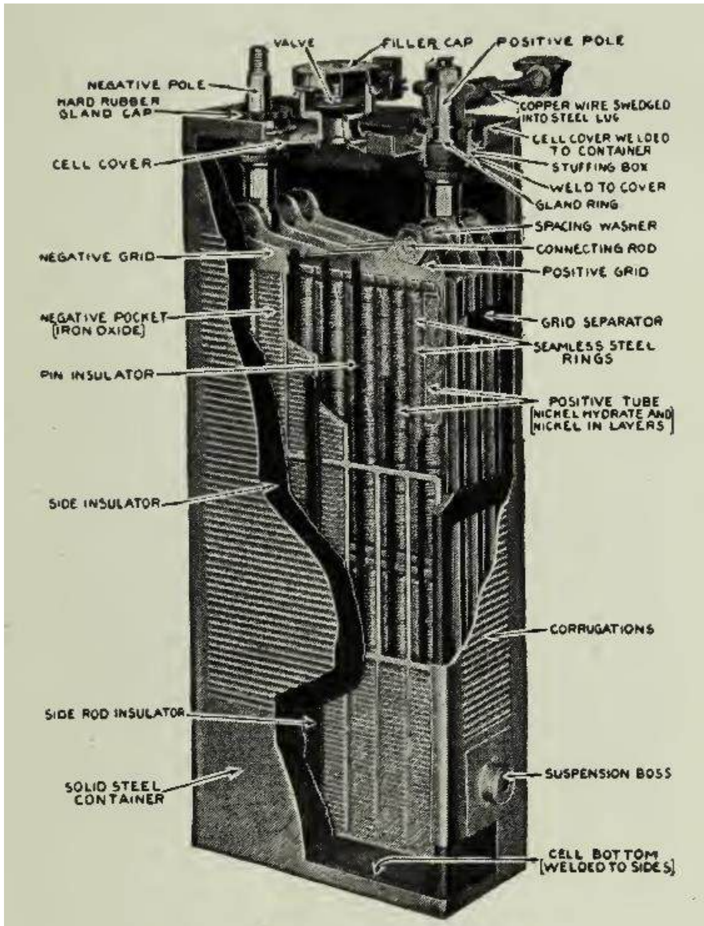
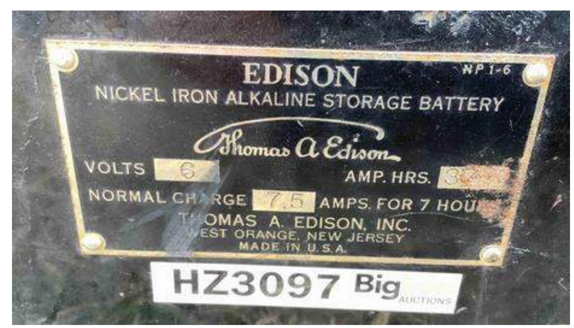


Fig. 46—Type A-4 Cell Assembly.



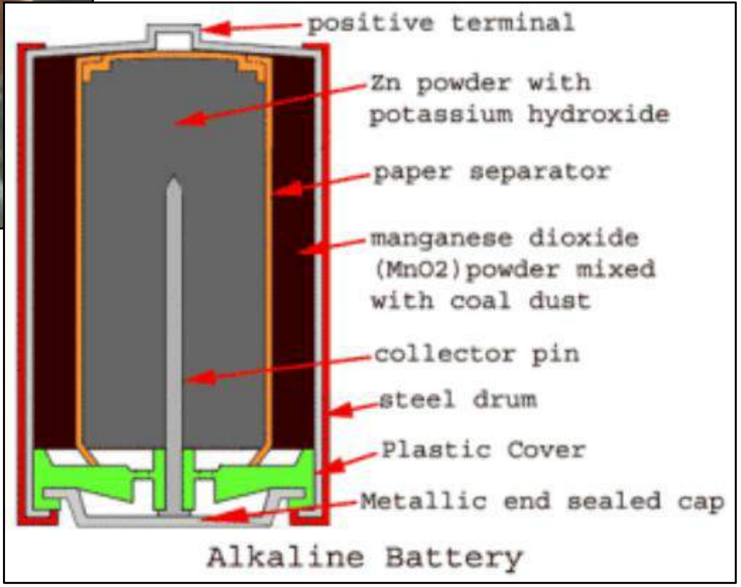
The NiFe cell was more tolerant of overcharging than Junger’s NiCd battery but required 120 – 150% of discharged capacity to charge

History of the Battery

- 1949 – Lew Urry, a Canadian, developed the alkaline-manganese battery for Eveready Battery Co. It lasted 5 to 10 times longer than zinc-carbon cells

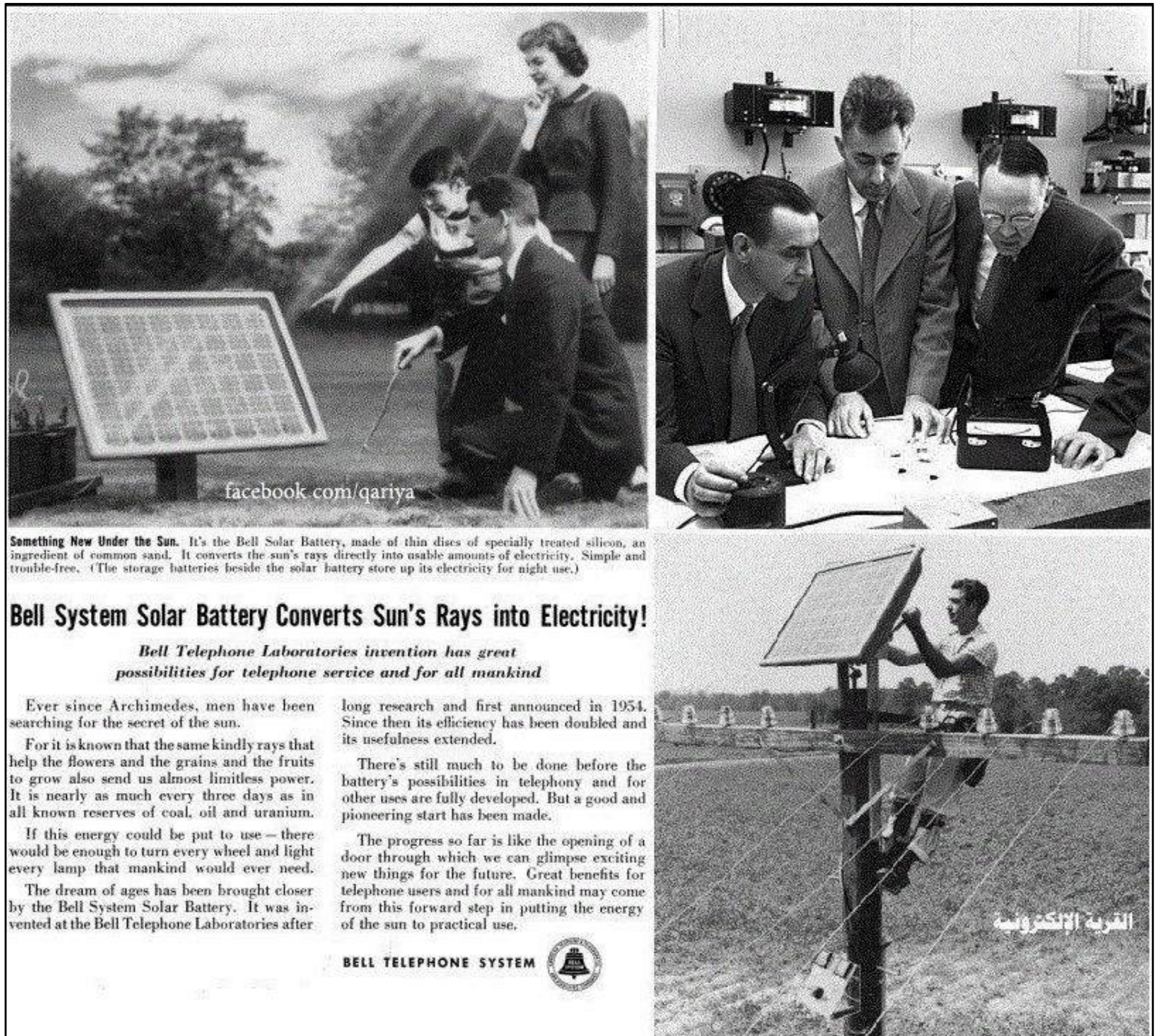
- Voltage stayed more stable instead of dropping off quickly
- Better performance at higher currents

- Initially cost 2-3x as much as zinc-carbon batteries but the cost per watt-hour was much less



History of the Battery

- 1954 – Pearson, Fuller and Chapin invented the first solar battery for Bell Laboratories in New York – about 6% efficient



Something New Under the Sun. It's the Bell Solar Battery, made of thin discs of specially treated silicon, an ingredient of common sand. It converts the sun's rays directly into usable amounts of electricity. Simple and trouble-free. (The storage batteries beside the solar battery store up its electricity for night use.)

Bell System Solar Battery Converts Sun's Rays into Electricity!

Bell Telephone Laboratories invention has great possibilities for telephone service and for all mankind

Ever since Archimedes, men have been searching for the secret of the sun.

For it is known that the same kindly rays that help the flowers and the grains and the fruits to grow also send us almost limitless power. It is nearly as much every three days as in all known reserves of coal, oil and uranium.

If this energy could be put to use – there would be enough to turn every wheel and light every lamp that mankind would ever need.

The dream of ages has been brought closer by the Bell System Solar Battery. It was invented at the Bell Telephone Laboratories after long research and first announced in 1954. Since then its efficiency has been doubled and its usefulness extended.

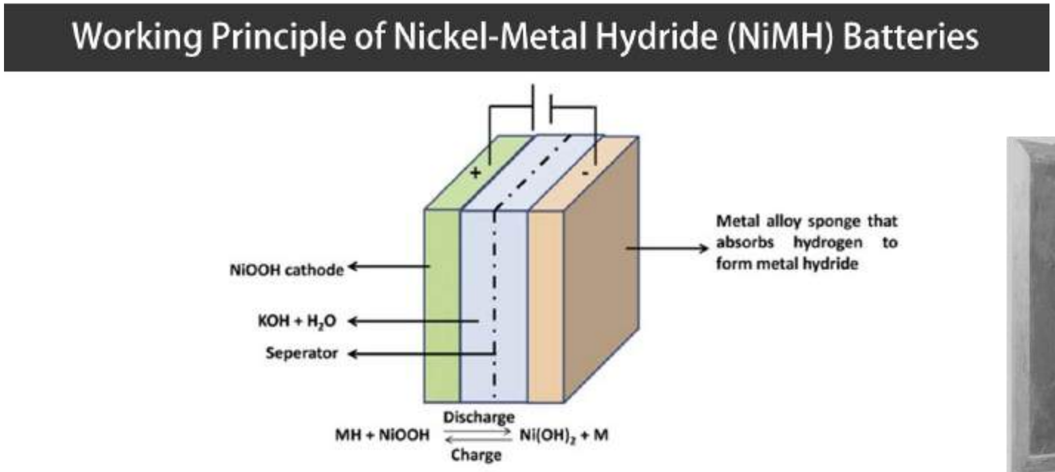
There's still much to be done before the battery's possibilities in telephony and for other uses are fully developed. But a good and pioneering start has been made.

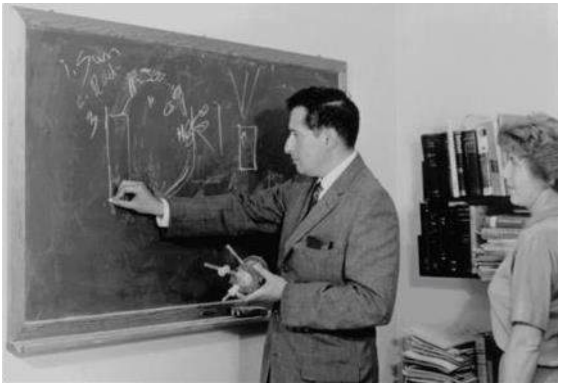
The progress so far is like the opening of a door through which we can glimpse exciting new things for the future. Great benefits for telephone users and for all mankind may come from this forward step in putting the energy of the sun to practical use.

BELL TELEPHONE SYSTEM

History of the Battery

- **Late 1960s –** Stanford Ovshinsky invented (NiMH) Nickel-metal hydride cells

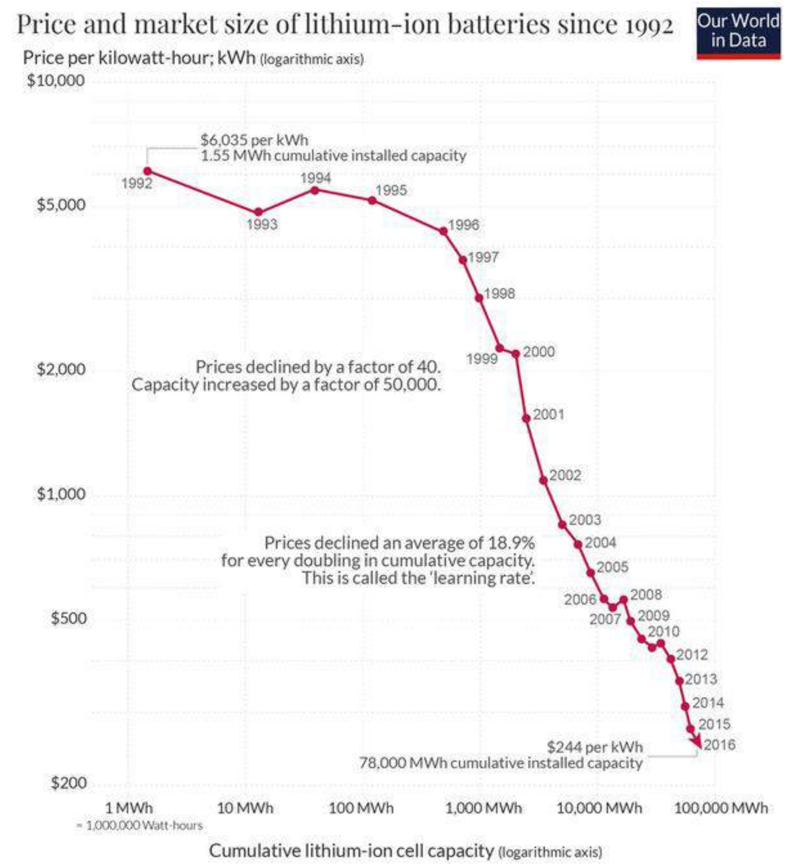




- Improvement over NiCd where cathode uses a hydrogen absorbing alloy instead of Cd.
- Typically 2 to 3 times the capacity of NiCd batteries of same size, with higher energy density, although about only half of lithium-ion batteries
- By 2008, more than 2 million hybrid cars worldwide were manufactured with NiMH batteries
- By 2010, NiMH was in decline due to Li-Ion batteries
- By 2015, BASF improved NiMH microstructure that made them more durable and allowed specific energy to reach 140 watt-hours per kg

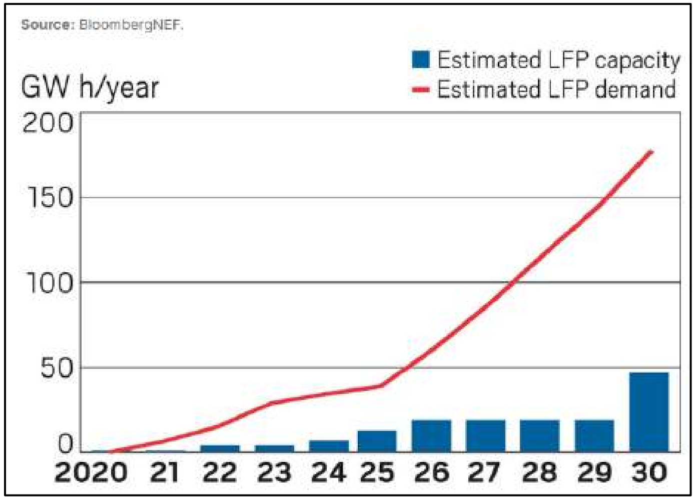
History of the Battery

- **1991 –** Sony Corp. started commercial sales of the first rechargeable Li-Ion cells. Numerous improvements were made by groups in the USA, China, Japan and South Korea.
- **2011** – Li-Ion batteries accounted for 66% of all rechargeable battery sales in Japan
- **2012** – Industry produced about 660 million cylindrical Li-Ion cells - the 18650 size by far the most popular.
- **2014** - The Tesla Model S EV needed 7,104 of these cells per car – about 40% of global production ➔ shifted to 3,000+ mAh cells in flat polymer cells
- **2019** – NCM (lithium nickel cobalt manganese oxide) became commercially available and had better energy density



History of the Battery

- **2003–** First **LFP ($LiFePO_4$)** batteries developed in Quebec. A German company recognized the significance and funded a plant near Montreal in 2005 but was not successful. A spin-off from MIT tried to manufacture their own version in 2009 but went bankrupt in 2012.
- **2010** - The Chinese developed their own solid-state process that solved many cost issues and led to a 100-fold increase in number of units produced between 2010 to 2016. The American and Canadian patent owners agreed not to charge the Chinese licensing fees if they kept the batteries in China. But the patents eventually expired and the Chinese now hold a virtual monopoly on production. Large factories are now being built with Chinese-licensed technology around the world to meet the demand of EVs and other devices



US demand for LFP batteries in passenger EVs is expected to outstrip local production capacity

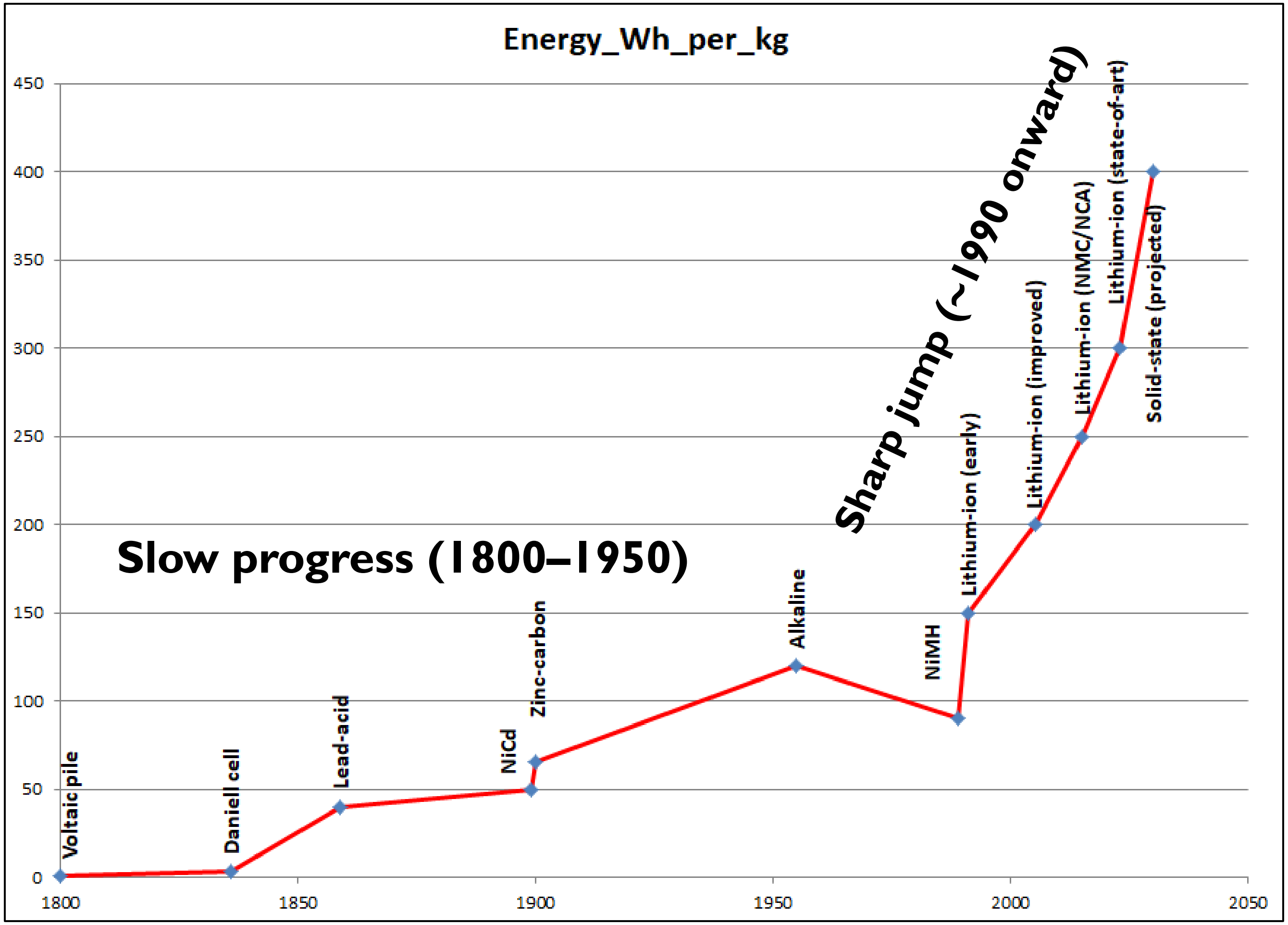
Multiple modules wired in series & parallel to create 2800 Ah 52V battery. Total capacity is 146 kWh. The busbar is rated for 700 amp DC to allow for high currents.

History of Batteries - Summary

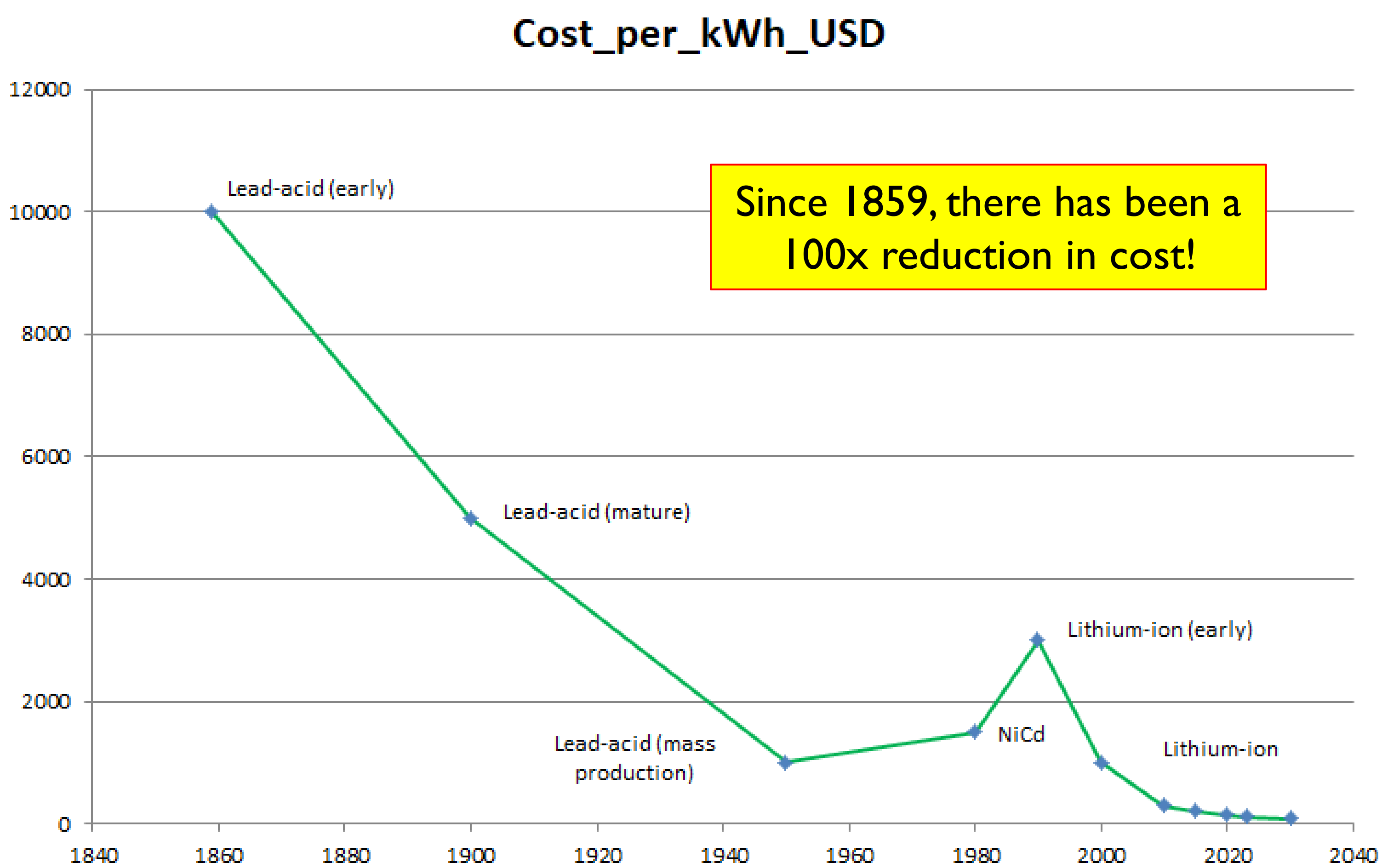
Below is a **simplified historical dataset** showing *approximate* gravimetric energy density (Wh/kg) for major battery types from the Voltaic pile to modern systems based on Lithium-ion battery.

Era	Battery Type	Chemistry	Energy Density (Wh/kg)	Notes
1800	Voltaic pile	Zn–Cu	~0.5–1	First battery, very inefficient
1836	Daniell cell	Zn–Cu sulfate	~1–5	More stable than Voltaic pile
1859	Lead-acid battery	Pb–acid	~30–50	First rechargeable battery
1899	NiCd	Nickel–cadmium	~40–60	Good cycle life, toxic
1900s	Zinc–carbon	Zn–MnO_2	~50–80	Early consumer batteries
1950s	Alkaline	Zn–MnO_2 (alkaline)	~80–150	Better shelf life
1980s	NiMH	Nickel–metal hydride	~60–120	Used in early hybrids
1991+	Li-ion	Lithium-ion	~150–300	Huge leap in density
2010s+	Advanced Li-ion	NMC, NCA variants	~200–350	EV-grade cells
Emerging	Solid-state (prototype)	Li-metal	~300–500+	Not yet mainstream

Energy Density Vs Time



Energy Cost Vs Time



Batteries for Ham Radio

Today, the dominant chemistry for SOTA/POTA is the:
Lithium Iron Phosphate Battery ($LiFePO_4$)

$LiFePO_4$ batteries Versus LiPo (Lithium Polymer) batteries

- Lower energy density but LiPo less safe (more prone to thermal runaway)
- More tolerant of overcharging, over-discharging and physical damage (to a degree)
- Flatter discharge curve and more predictable behaviour, which helps reduce stress during use
- Cost about 20 to 40% more but are actually cheaper over time. This is because $LiFePO_4$ batteries can be recharged 2,000 – 7,000 cycles, while LiPo batteries only 300 – 1,000 cycles.
- 1.5x to 2x heavier
- Sit close to 13 V for most of their use
- Take longer to charge as LiPo optimized for high current and speed while $LiFePO_4$ batteries are optimized for stability and longevity
- Both types require BMS (Battery Management System) to prevent overcharging, over-discharging, overcurrent (overheating) and cell imbalance – Normally built-in with quality power banks, packs.

POTA/SOTA Scenarios

Scenario A: QRP: 5 – 10W

KX-2

Successor of FT-817

IC-705

BANDS	HF ONLY	HF+VHF/UHF	HF+VHF/UHF
Power	~10W	~6W	~5-10W
Weight	Very Light	Medium	Heaviest
Battery	Internal Option	Internal (limited)	Internal (high drain)
Best for	Ultralight SOTA	All-band portability	Feature-rich portable
Recommended battery	3-6 Ah $LiFePO_4$ pack	6-10 Ah $LiFePO_4$	4 – 6 Ah
Battery Weight	< 1 kg	2 – 2.5 kg	1-1.5 kg
Real-world runtime	3-6 Hours	4-8 Hours	4-7 Hours

POTA/SOTA Scenarios

Scenario A: QRP: 5 – 10W

KX-2

Successor of FT-817

FT-818ND

IC-705

BANDS	HF ONLY	HF+VHF/UHF	HF+VHF/UHF
Battery	Bioenno BLF-1203AB	Bioenno BLF-1206A	Bioenno BLF-1212AS
Weight	< 1 kg	0.7 kg	~ 1.6 kg
Capacity	~38 Wh	~ 76 Wh	~115 Wh
Run time	~2-4 hours QRP	~3-6 hours SSB/CW	4-8 hours (SSB/Mixed Use)
Price	~$70 - $110	~$150	~$230
Comments	Best balance of weight vs runtime	Handles FT8 duty much better	Perfect voltage match (12.8-13.2V)

POTA/SOTA Scenarios

<u>Scenario B: Portable – 100 Watts</u>

Yaesu FT-891

ICOM IC-7300

Yaesu FT-710

BANDS	HF/50 MHz	HF/50 MHz	HF/50 MHz
Field Strength	Ultra-portable, rugged	"Base station in a box"	Modern SDR field hybrid
Power	~10W	~6W	~5-10W
Weight	1.9 kg	4.2 kg	4.5 kg
Recommended battery	10-20 Ah $LiFePO_4$	20-40 Ah $LiFePO_4$	15-30 Ah $LiFePO_4$
Battery Weight	~ 2 kg	~3 – 6 kg	~2.5 – 5 kg
Real-world runtime	3-6 Hours	3-6 Hours	3-5 Hours

Portable Power Stations

A typical portable power station contains:

- A $LiFePO_4$ or lithium-ion battery
- A battery management system (BMS)
- A DC → AC inverter (for 120V outlets)
- Charging inputs (AC wall, car, solar)

Two ways they power ham radios

1) DC direct (best option if available)
    - 12V car port or regulated DC output
    - Efficient
    - Less noise risk
2) AC inverter → power supply → radio
    - 120V AC output → external 13.8V supply → radio
    - More losses
    - Sometimes more RF noise

Example: Bluetti EB70S Portable Power Station has AC + DC + USB outputs and can accept solar input, but is just a battery/inverter unit ~ $800

Solar

Ultralight POTA solar backpack

Recommended solar size: 100W foldable panel

Typical examples:

- Jackery SolarSaga 100W class
- Bioenno-style folding 100W panels
- Generic "100W ETFE folding panels"

$259

Best use case

- FT-891 HF/50 MHz Transceiver
- Light IC-705 / QRP backup charging
- Daytime "top-up" charging only

What it can realistically do

- ~300–500 Wh per day in good sun (Canada summer, ideal angle)
- Enough to **slow-charge a 10–20 Ah $LiFePO_4$ battery**

Key limitation

- Not enough to *run 100W continuously*
- Works best as **battery replenishment**

Jackery Explorer 1000 v2 Portable Power Station,1070Wh LiFePO4 Battery,1500W AC/100W USB-C Output, 1 Hr Fast Charge, Solar Generator $599

Solar

Ultralight POTA solar backpack – Example: Jackery SolarSaga 100 W class

$259

Cell type: Monocrystalline
Conversion efficiency: up to ~25%
Typical output (real world): ~60 – 90%
Voltage (Vmp): ~18-20 V (at max power)
Current (Imp): ~5.5 A (at max power)
Ports: DC (for Jackery power stations)
USB-A + USB-C for device charging
Weight: 2 kg
Features: Dust/water resistant, fast kickstand,
foldable, flexible

Since this unit produces ~18V, a “charge controller” and a 12V battery (or DC-DC buck converter) are required between the solar panel and the radio.

So what is a ***Charge Controller?***

Solar – Charge Controller

Introducing the **MPPT Controller**: **M**aximum **P**ower **P**oint **T**racking

- Because solar panels do not produce constant power over time, the voltage and available current may vary considerably. This produces a **"sweet spot"** where a particular voltage and current can maximize delivered power
- The **MPPT controller** continuously finds the sweet spot and **delivers optimal voltage/current to a battery** for storage or to do electrical work
- The MPPT controller provides a bridge to a desired voltage (such as for a 12 V - 13.8 V transceiver)

For example, the solar panel may be delivering ~18 V @ ~ 5.5 A → 100 W to the controller but the controller converts it to ~13.8 V @ 7+ A to power a radio

MPPT:

- 90-98% efficient
- Work great when panel voltage is higher than the battery
- Ideal for portable solar panels
- More expensive than PWM (basic alternative), which waste potential power (can lose 20-30% output)

Charge Controller - Options

$122.42

Victron Energy SmartSolar
MPPT 100V 20 amp

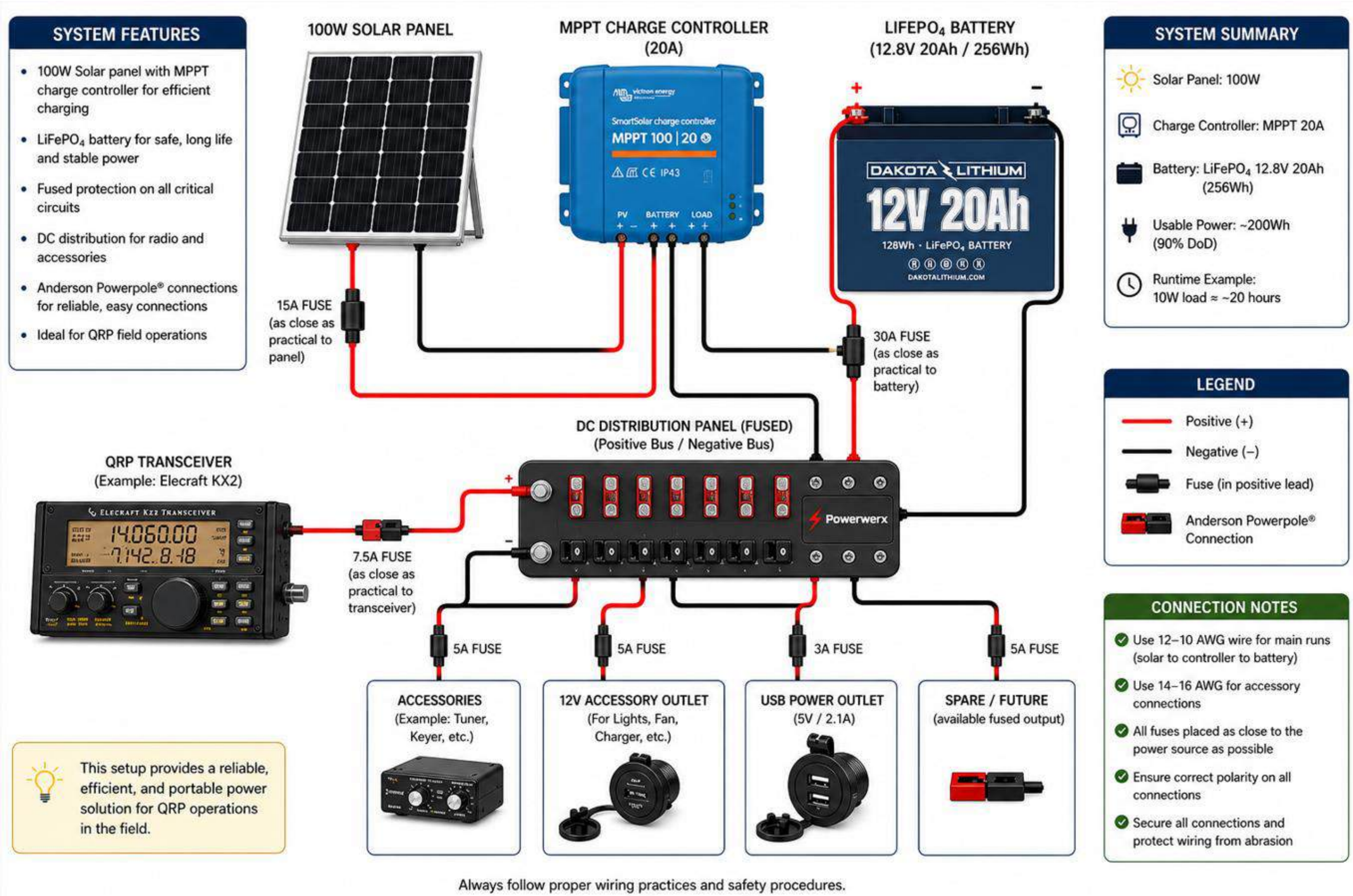
$151.61

Renogy Rover 12V @ 20A

For a KX2 or FT-818:

- 100W solar panel
- 12V LiFePO4 battery (10-20 Ah ideal)
- MPPT controller

Complete QRP POTA System



Note: ChatGPT could not get wiring correct after 7 attempts!

What to Look For in a Ham Radio Battery – A Review

1. Proper Voltage (12V)
   - Most transceivers designed for 13.8V. A 12V $LiFePO_4$ battery typically holds steady 13.2-13.4V
   - $LiFePO_4$ batteries require a compatible charger

2. Sufficient Capacity (Ah Rating – based on radio's current draw)
   - 3Ah-6Ah: HT, QRP, APRS beacons
   - 9Ah-15Ah: 10-20W portable transceivers
   - 20Ah-40Ah: 50-100W HF/VHF transceivers in the field
   - 100Ah: Base station, off-grid shack, multi-day emcomm

3. Lightweight and Compact Design
   - ABS enclosures (durable, non-conductive, heat-tolerant, light)
   - Anderson Powerpole connectors
   - Form factors that fit backpacks or go-kits

Battery Safety: Warning Signs & Actions

Common Warning Signs (All Battery Types)

- Swelling / bulging (especially in Lithium-Polymer Battery)
- Overheating during use or charging
- Leaking fluid or unusual odor
- Corrosion on terminals (common in Nickel-Metal Hydride Battery)
- Rapid capacity loss / won’t hold charge
- Physical damage (puncture, dent, crushed case)

Lithium-Based Batteries (LiPo, LFP, NMC, NCA)

Includes:

- Lithium Iron Phosphate Battery
- Lithium Nickel Manganese Cobalt Oxide
- Lithium Nickel Cobalt Aluminum Oxide

Watch for:

- Swelling (gas buildup)
- Excess heat or thermal runaway risk
- Hissing, popping, or smoke

Actions:

- **Stop using immediately**
- Move to a **non-flammable area** (concrete, metal container)
- **Do not puncture or compress**
- Allow to cool—do not handle if hot
- Dispose at certified battery recycling facility

Battery Safety, Continued…

Nickel-Based Batteries (NiMH)

Watch for:

- Leakage (alkaline electrolyte)
- Corroded terminals
- Reduced runtime

Actions:

- Avoid skin contact with leakage
- Clean terminals safely (if minor corrosion)
- Replace if leaking or degraded
- Recycle properly

Charging Safety (All Types)

- Use the correct charger for the battery type
- Never charge damaged or swollen batteries
- Avoid overcharging (use protected systems like a Battery Management System)
- Charge on non-flammable surfaces
- Do not leave charging batteries unattended

What NOT to Do:

- Do not puncture, crush, or incinerate
- Do not mix old and new batteries
- Do not use counterfeit or damaged chargers
- Do not dispose in regular trash

Battery Safety, A Warning…

Mislabeled / Counterfeit Batteries

Warning Signs:

- Unbranded or suspicious labeling (no manufacturer, vague specs)
- Claims that don’t make sense (e.g., very high capacity in a small cell)
- Poor build quality (loose wires, uneven seams, cheap connectors)
- Wrong chemistry in the wrong format
  - e.g., a basic cell disguised as a Lithium-Polymer Battery
- No safety markings (CE, UL, etc.)
- Unusual weight (too light can mean less active material inside)

Why It’s Dangerous

- May lack a proper BMS (Battery Management System)
- Poor internal separators → higher short-circuit risk
- Inaccurate ratings → overheating or overloading
- Increased risk of fire, leakage, or explosion

What To Do

- Buy from reputable manufacturers/suppliers
- Verify specs against known standards
- Inspect batteries before use
- Avoid mixing unknown batteries into critical systems

$LiFePO_4$ Optimization Tips

- Avoid Charging to 100% or discharging below 10%. Normal operating charge should be 20% to 80%
- Store batteries in a cool, dry location
- For long-term storage, keep charge around 40-60%
- Use a BMS (Battery Management System) for protection and balancing
- Keep terminals clean and connections tight
- Avoid charging below freezing temperatures (unless battery has protection)
- Avoid storing fully charged for long periods (run a small load after charging)
- Some recommend charging at least once every 2 months
- Some chargers switch to a low "float" standby current when battery pack is fully charged, so can be left plugged in. Many chargers do not have this.
- Fully charged cells reach about 3.65 V

State of Charge	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
1 Cell (3.2V)	3.00	3.20	3.22	3.25	3.27	3.29	3.32	3.35	3.40	3.65
4 Cells (12V)	12.00	12.80	12.88	13.00	13.08	13.16	13.28	13.40	13.60	14.60

The Future of Batteries

Most likely near-term successor to the $LiFePO_4$ battery: **Sodium-ion**

- Uses much cheaper and more abundant sodium
- Does not rely on lithium or cobalt supply chains
- Good cold-weather performance
- Lower fire risk
- Lower energy density (heavier/bulkier)
- Still early in commercial rollout
- Fits better in grid storage and backup power system

"True next-generation" lithium (most hyped technology):

- Higher energy density
- Much lower fire risk
- Faster charging potential
- Better cycle life in theory

Long-term Candidate: Lithium-sulfur (Li-S)

- Extremely high theoretical energy density
- Lightweight (for aviation/drones)
- Short cycle life today
- Still largely experimental

The Future of Batteries, Cont'd

Long-term Candidate 2: Aluminum-Air (Al-Air)

- Aluminum reacts with O_2 from the air
- Extremely high energy density
- Low cost due to abundant aluminum
- Very lightweight
- Not rechargeable as aluminum is consumed in the process
- You refuel by replacing aluminum plates
- Electrolyte management/corrosion issues

Long-term Candidate 3: Aluminum-Ion (Al-ion)

- Similar to Li-ion but with graphite cathodes
- "Next-gen rechargeable" contender
- Long cycle life (thousands of cycles)
- Non-flammable electrolytes (safer than Li-ion)
- Abundant aluminum and low cost
- Low voltage (~2V or less per cell)
- Lower energy density than Lithium (currently)

Long-term Candidate 4: Aluminum-Graphene

- Still very early stage – nothing to buy
- Improved energy density and stability


THE END