Lithium-Ion and other Batteries

Types of Storage Batteries

Lead-Acid (invented 1859)

- The anode is lead and the cathode is lead dioxide in the fully charged state.
- These electrodes are in an electrolyte (sulphuric acid) containing hydrogen ions (H^+) and bisulphate ions (HSO_4).
- When discharged both are covered with lead sulphate.
- Now two main types, Deep cycle and Starter Motor. Widely used

Types of Storage Batteries

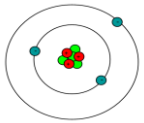
Nickel-cadmium

- The nickel-cadmium (NiCad) battery had an anode of cadmium and cathode of nickel hydroxide.
- The electrolyte was potassium hydroxide. Had a memory problem.

Nickel-metal hydride (NiMH)

- Problems with NiCad batteries led to the cadmium anode being replaced with a hydrogen-absorbing metal alloy that can hold up to 7 per cent hydrogen by weight.
- The anode is the hydrogen; the metal is a storage vessel for it. May be used in hybrid cars.

What is Lithium?



Lithium is a metal that is found naturally bonded to other elements in igneous rocks and mineral springs. It is the lightest metal and has the lowest density of any solid element. Although it is a metal, it is soft enough to cut with a knife.

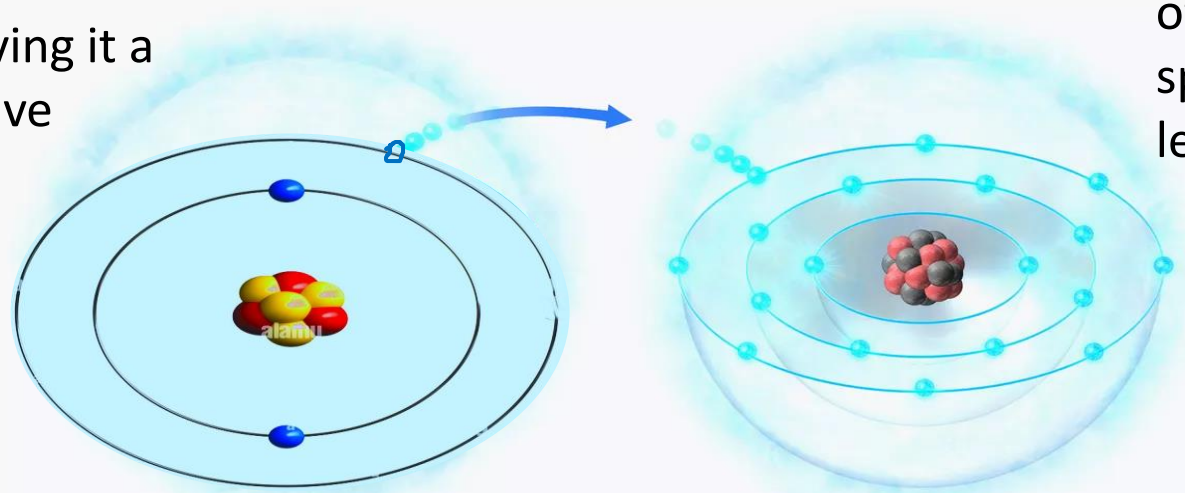
Along with hydrogen and helium, lithium was one of the three elements produced in large quantities by the Big Bang.

The world's top four lithium-producing countries are Australia, Chile, China and Argentina. Chile, Bolivia and Argentina contain a region known as the Lithium Triangle, believed to contain over 75% of existing known lithium reserves.

Much of the lithium mined globally comes from either "spodumene", the mineral contained in hard rocks found in places such as Australia or from salty brine pumped directly out of the ground, as it is in locations in Chile.

Ions

An ion is defined as an atom or molecule that has gained or lost one or more of its valence electrons, giving it a net positive or negative electrical charge.



Formation of Positive Lithium Ion

The electron from the valence level of the Lithium atom moves to a space the other atom's valence level

The Nobel Prize in Chemistry 2019

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John B. Goodenough

Prize share: 1/3

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M. Stanley Whittingham

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Akira Yoshino

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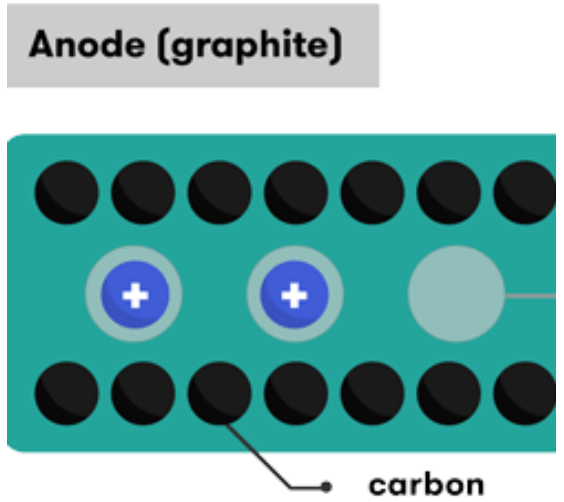
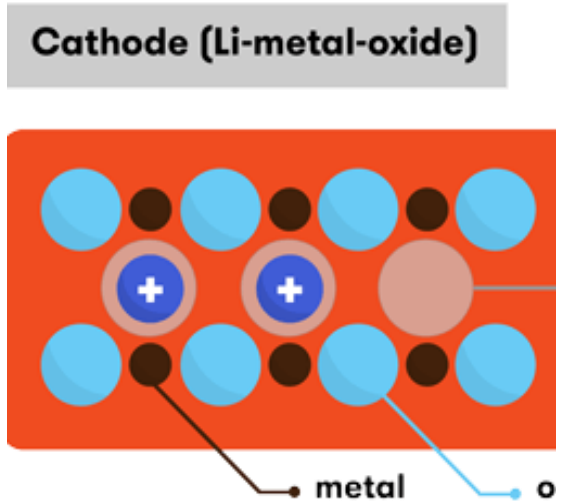
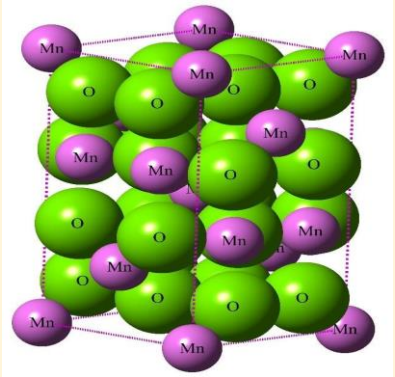
Lithium-Ion Batteries (LiB)

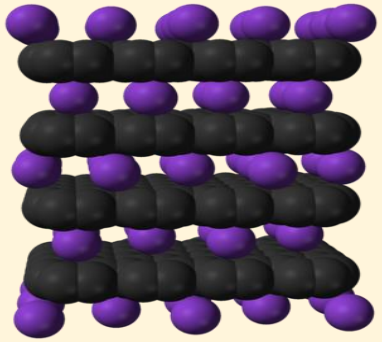


- **Lithium ions** (Li^+) are involved in the reactions driving the battery.
- Both electrodes, anode and cathode, in a lithium-ion cell are made of materials which can **intercalate** or 'absorb' lithium ions.

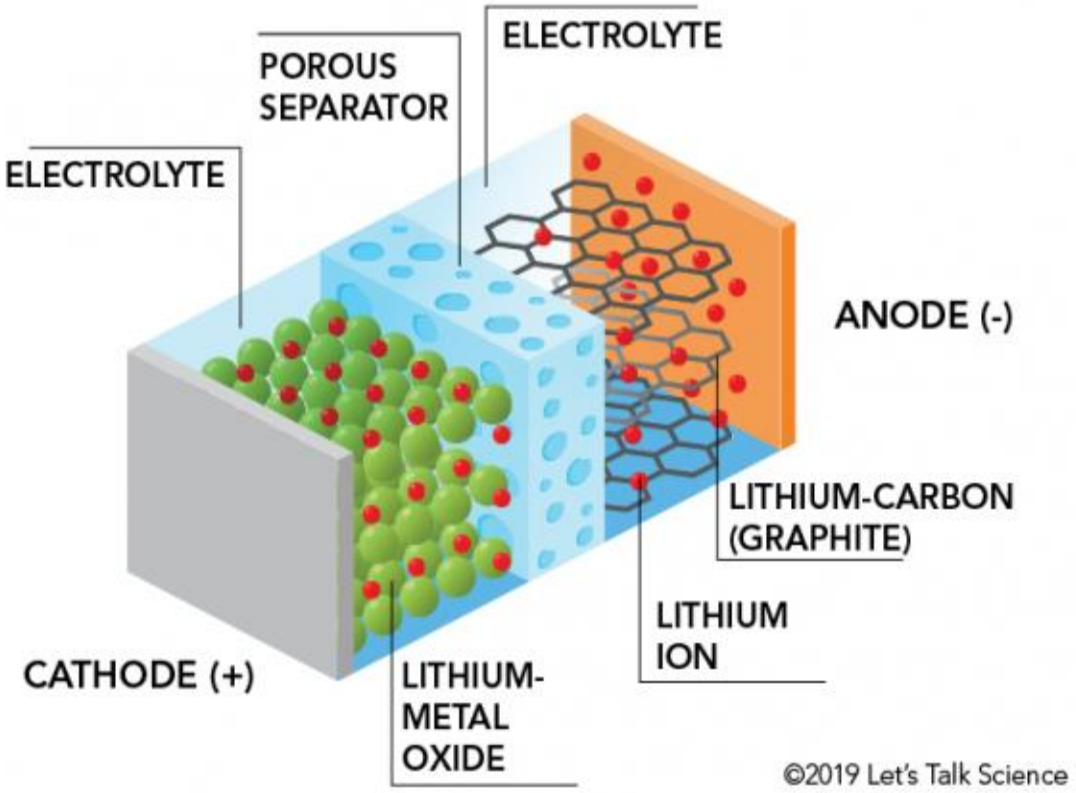


- **Intercalation** (Whittingham) is when charged ions of an element can be 'held' inside the structure of a host material without disturbing it.
- The lithium ions are 'tied' to an electron within the anode.
- When the cell discharges, the ions are released from the anode, and move through the electrolyte back to the cathode. Electrons travel via an external circuit

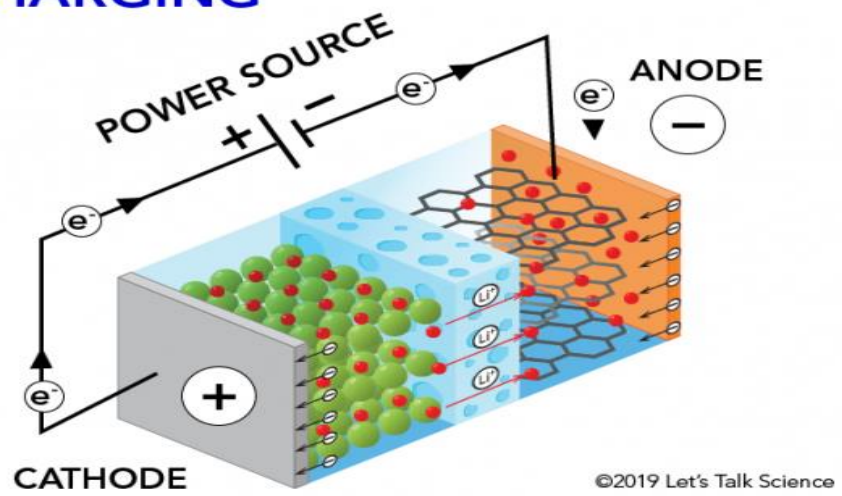




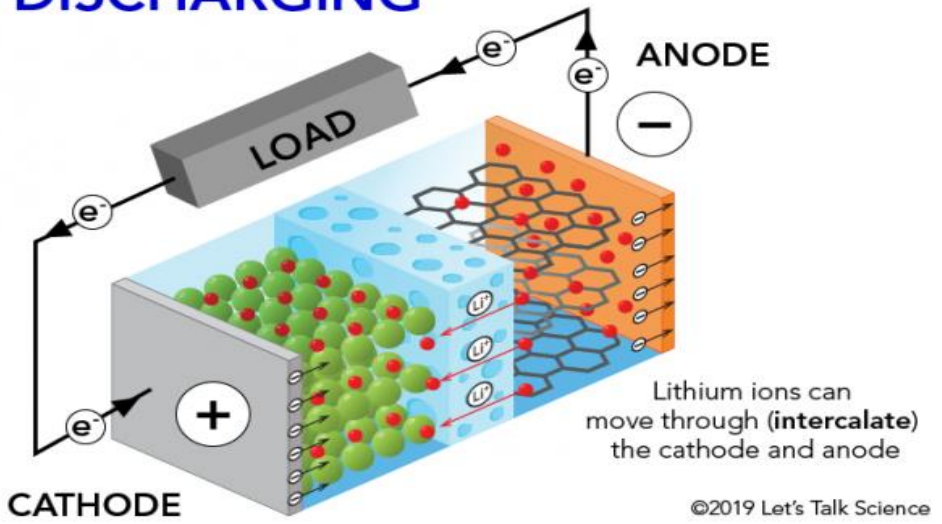
PARTS OF A LITHIUM-ION BATTERY



CHARGING



DISCHARGING



www.energy.gov/energysaver/articles/how-lithium-ion-batteries-work

Types of Lithium Batteries

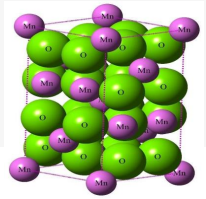
Lithium cobalt oxide ($LiCoO_2$) (John Goodenough)

- The most common lithium-ion cell and has an anode of carbon and cathode of lithium cobalt oxide.
- Has the greatest energy density, used in our phones, digital cameras, laptops and some cars.
- The anode can overheat. If oxygen and heat are combined, the results can be disastrous. Chemicals used in the electrolyte are flammable.

Lithium iron phosphate ($LiFePO_4$)

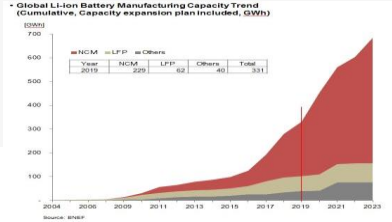
- This cell has a high discharge rate and has good thermal stability. Used for electric vehicles and power tools, and at power stations. It also has a long cycle life.
- However, it has a lower energy density than a lithium cobalt oxide cell, and a higher self-discharge rate.

Lithium manganese oxide ($LiMn_2O_4$)



- This type of LiB has a cathode made from lithium-manganese spinel ($Li^+Mn^{3+}Mn^{4+}O_4$). Spinel is a type of mineral with a distinctive structure.

- It has very good thermal stability, improving the battery's safety.



Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$ or NMC)

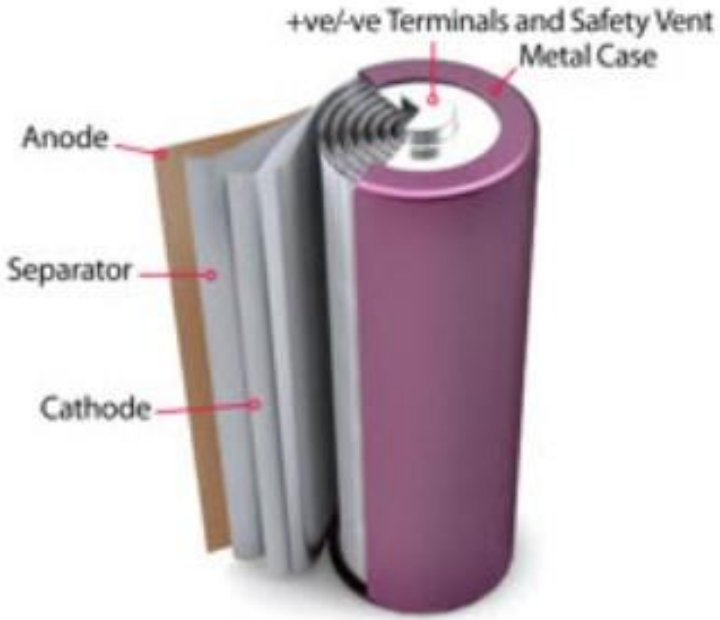
- Nickel provides a high specific energy and, when added to the stable structure of the manganese spinel, results in a battery with low internal resistance, high charging rate, good stability and safety. Widely used in electric cars.

Electrolytes

- Liquid electrolytes in LiBs consist of lithium salts in an organic solvent, such as ethylene carbonate, dimethyl carbonate, and diethyl carbonate.

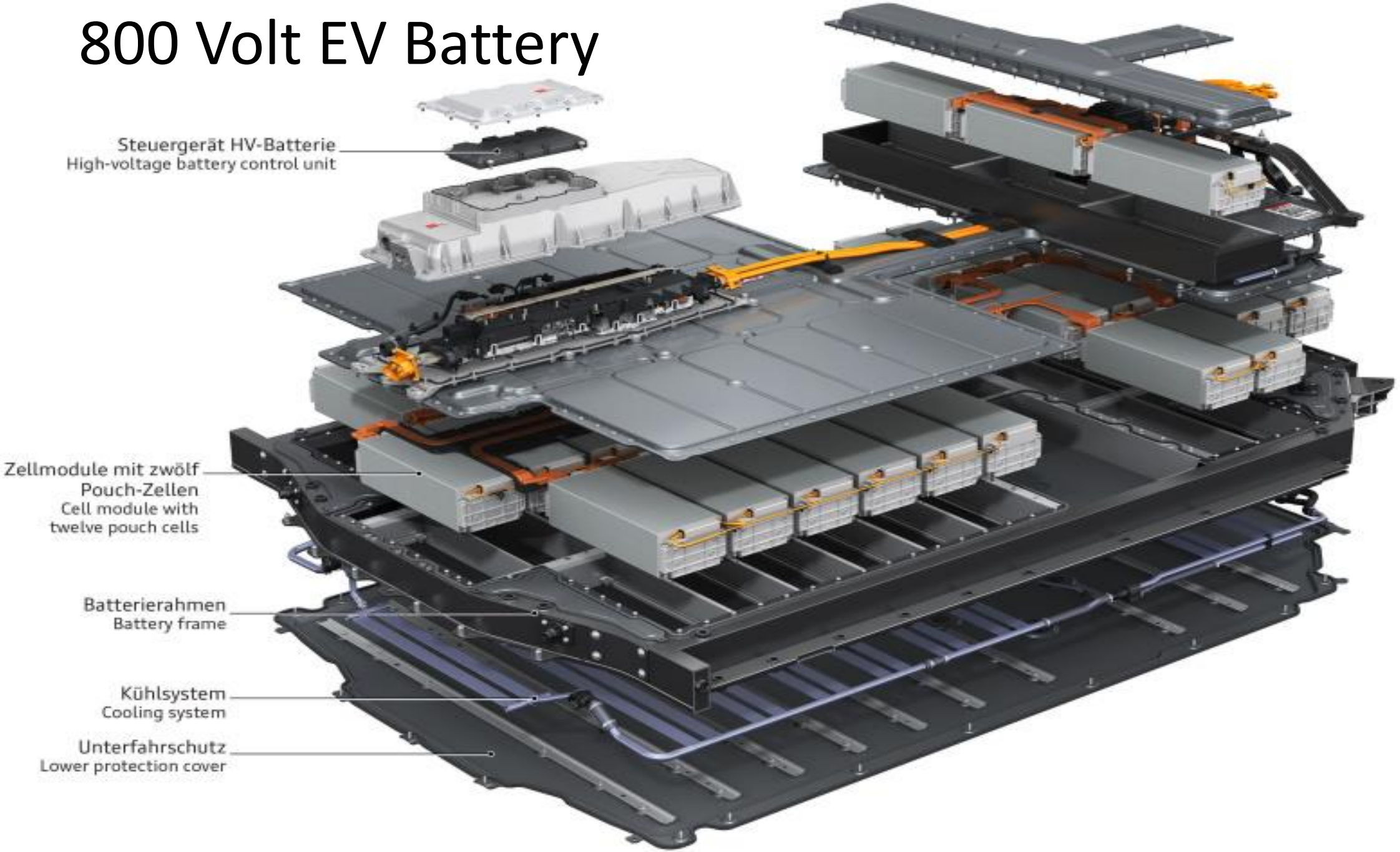
- Replacing the liquid electrolyte in an LiB with a solid electrolyte improves the battery's safety and makes it lighter. The polymer is extremely thin, it also enables greater flexibility —can be made to be extremely compact.

Packaging



	Cylindrical	Prismatic	Polymer
Pros	Low Cost (High Volume)	High Energy Density, Efficient Packaging	Flexible Form
Cons	Bulky Size	Standardized	High Costs, Hard to Scale
Applications	E-Bike, Garden Tool, Power Tool, Vaccum Cleaner	Digital Camera, Mobile Phone	Mobile Phone, Laptop Computer, Tablet

800 Volt EV Battery



Waratah Grid Battery - 1680 MWhrs
Maximum Power 850 MW (for 2 hours)

https://anero.id/energy/renewable-energy

Battery Voltages

- A single LiB cell produces a voltage of 3.6 volts or higher, depending on the cathode materials.

- Until recently the standard voltage used by Evs was 400 Volts. Some manufacturers have increased that voltage to 800.

- A major benefit of a higher pack voltage is a reduction in the size of the wires needed for the charging cable. Another benefit is the reduction in weight due to the smaller size for some wires in the car. The battery size depends on kWhrs rather than voltage.

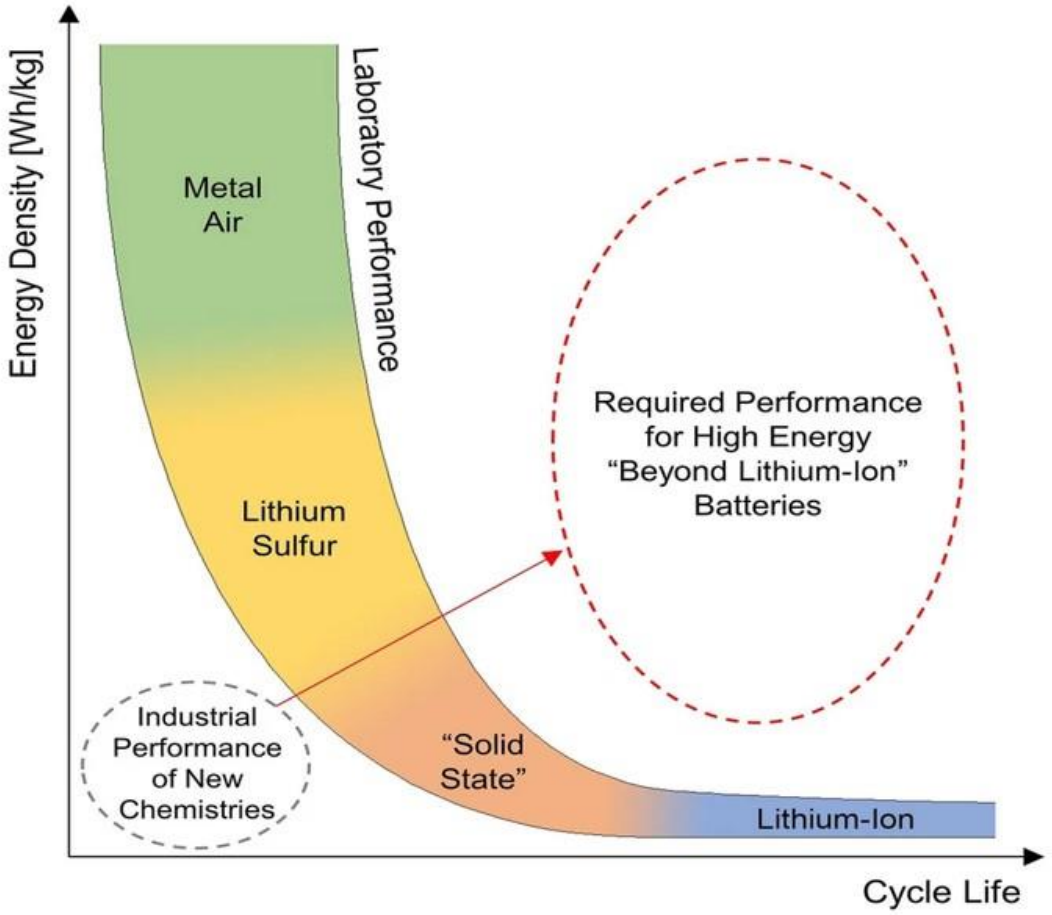
- A current of 1 kA requires wires of 380 mm^2 in area. A 5m charging cable weighs 37 kg. Half the current needed for the same power level with the 800 V pack needs wires 107 mm^2 in area weighing 12 kg.

Solid State Batteries

- In a conventional LiB, the anode and cathode actively store energy in the form of lithium and the separator provides good insulation between the electrodes.
- The charge carriers (lithium ions) are transported through a liquid electrolyte during the charging and discharging processes.
- The liquid electrolyte is the main difference between lithium-ion and solid-state batteries, because the latter uses composite cathodes and solid electrolyte separators

- By eliminating electrolyte solutions and using lithium-metal anodes (LMBs), an increase in energy density of up to 50 percent, and faster charging times can be obtained.

- Expected around 2030s. Increases power density, eliminates “Range Anxiety”. Makes recharging faster. Costs less?

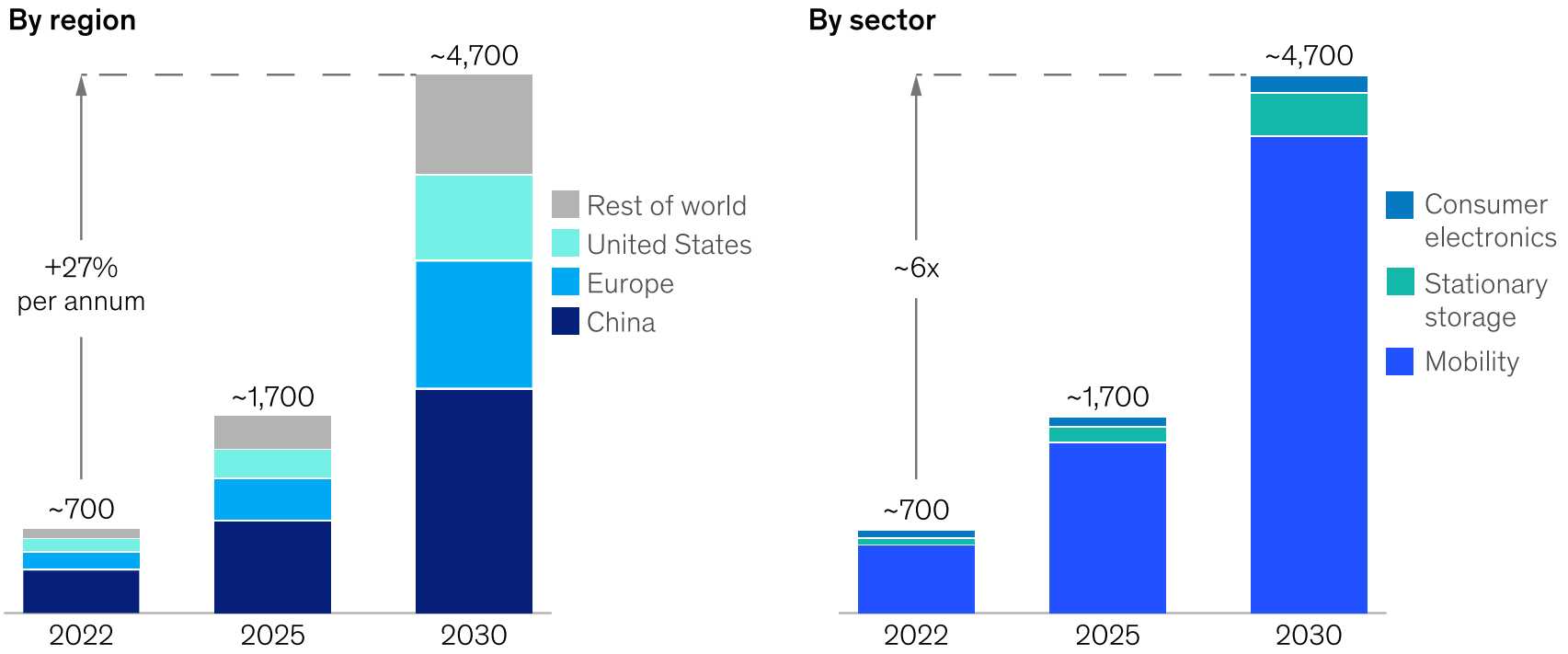


High-Energy Batteries: Beyond Lithium-Ion and Their Long Road to Commercialisation

- With the combination of energy, power, cyclability and cost, it seems that LiBs are the gold standard now.
- Many of the "beyond lithium-ion" alternatives are promising, although gaps to commercialisation remain.

Li-ion battery demand is expected to grow by about 27 percent annually to reach around 4,700 GWh by 2030.

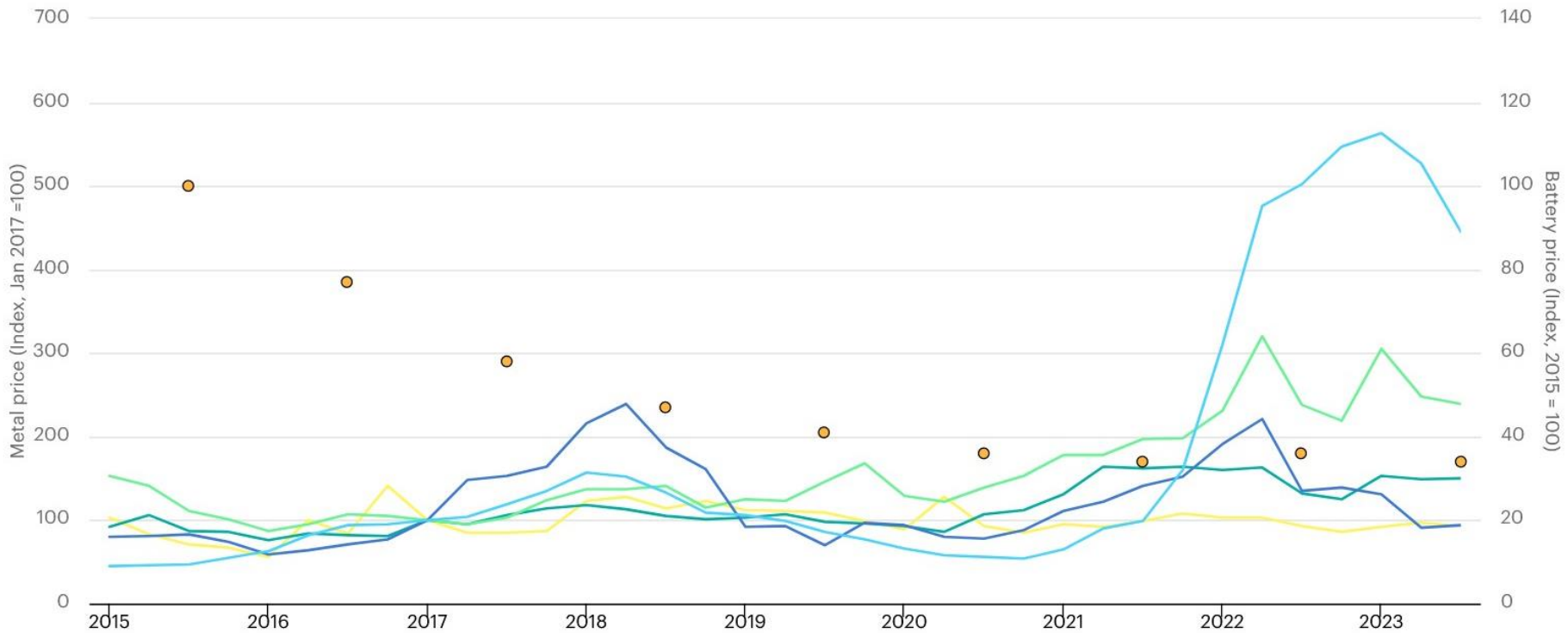
Global Li-ion battery cell demand, GWh, Base case



[1]Including passenger cars, commercial vehicles, two-to-three wheelers, off-highway vehicles, and aviation.
Source: McKinsey Battery Insights Demand Model

Price of selected battery materials and lithium-ion batteries, 2015-2023

Open



Lithium carbonate · Cobalt · Nickel · Copper · Manganese · Battery

THE END


Shredded and pulverized tires
Recycled tires
Pretreatment
Recovered carbon black
Pyrolysis