Chemical Energy Storage

Batteries, Fuel Cells and Flow Batteries

Recommended for grades 7 – 12

People for Energy and Environmental Literacy

Batteries are used every day in many aspects of life

Our lives are centered around energy storage

Batteries are Becoming Cheaper to Make

The decreasing cost of batteries comes as a result of electric vehicle advancements

2016: the cost of a lithium-ion battery was as low as

$270/kWh

By 2050: the cost of lithium-ion batteries is estimated to drop to between

$80 – $120/kWh

This cost is comparable to the cost of electricity from peaking generators.

A peaking generator is one that operates during times of high demand

2023: the cost of a lithium-ion battery was **133/kWh**

Energy Storage and it's impacts

01

Energy storage will affect the entire electricity value chain

- Peaking Plant
- Transmission lines
- Renewable Energy

02

Reducing Cost for Peak Energy at the Customer Level

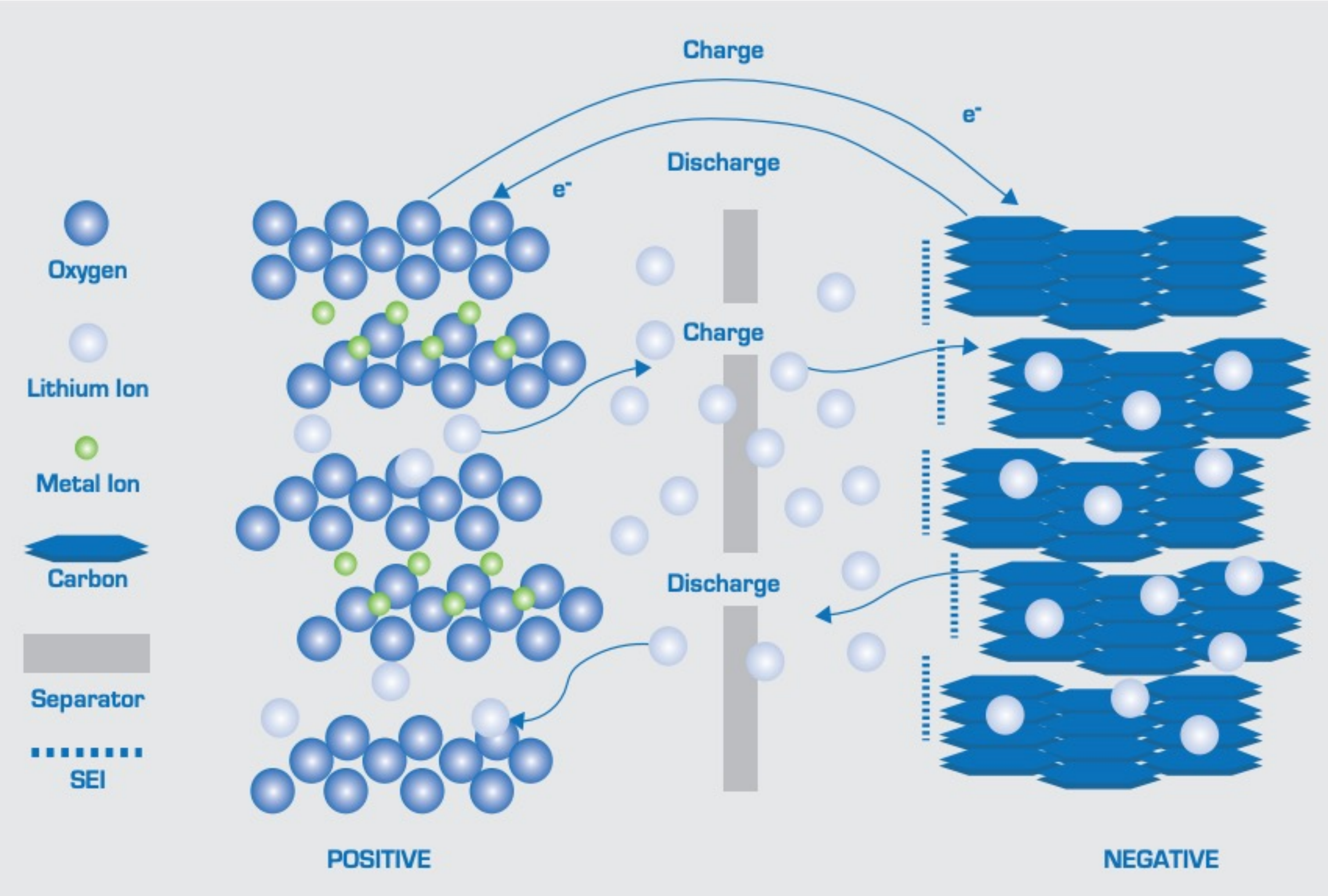
Chemical Energy Storage

Chemical	Batteries, fuel cells, thermochemical energy storage
Electrical	Capacitors, supercapacitors, superconducting magnetic energy storage (SMES)
Mechanical	Flywheels, pumped hydro, compressed air energy storage (CAES)
Thermal	Low and high temperature storage

Batteries

- Batteries are a type of solid-state chemical energy storage
- Types of batteries include:
  - Lead-acid battery
  - Nickel-based battery
  - Lithium-ion battery
- Batteries bring a range of applications both big and small
  - Portable electronics (cell phones, tablets, etc.), electric vehicles, forklift trucks, boats, emergency power.

- In a lithium-ion battery, the cathode (positive electrode) is made of lithium-metal oxide – i.e., cobalt, and the anode (negative electrode) is made of a carbon complex – i.e., graphite
- Ionization of lithium creates an electrical current
- Li is the lightest metal and has a high energy density per weight
  - Energy density is the amount of energy stored per unit volume
  - The higher the energy density, the more energy stored in the battery

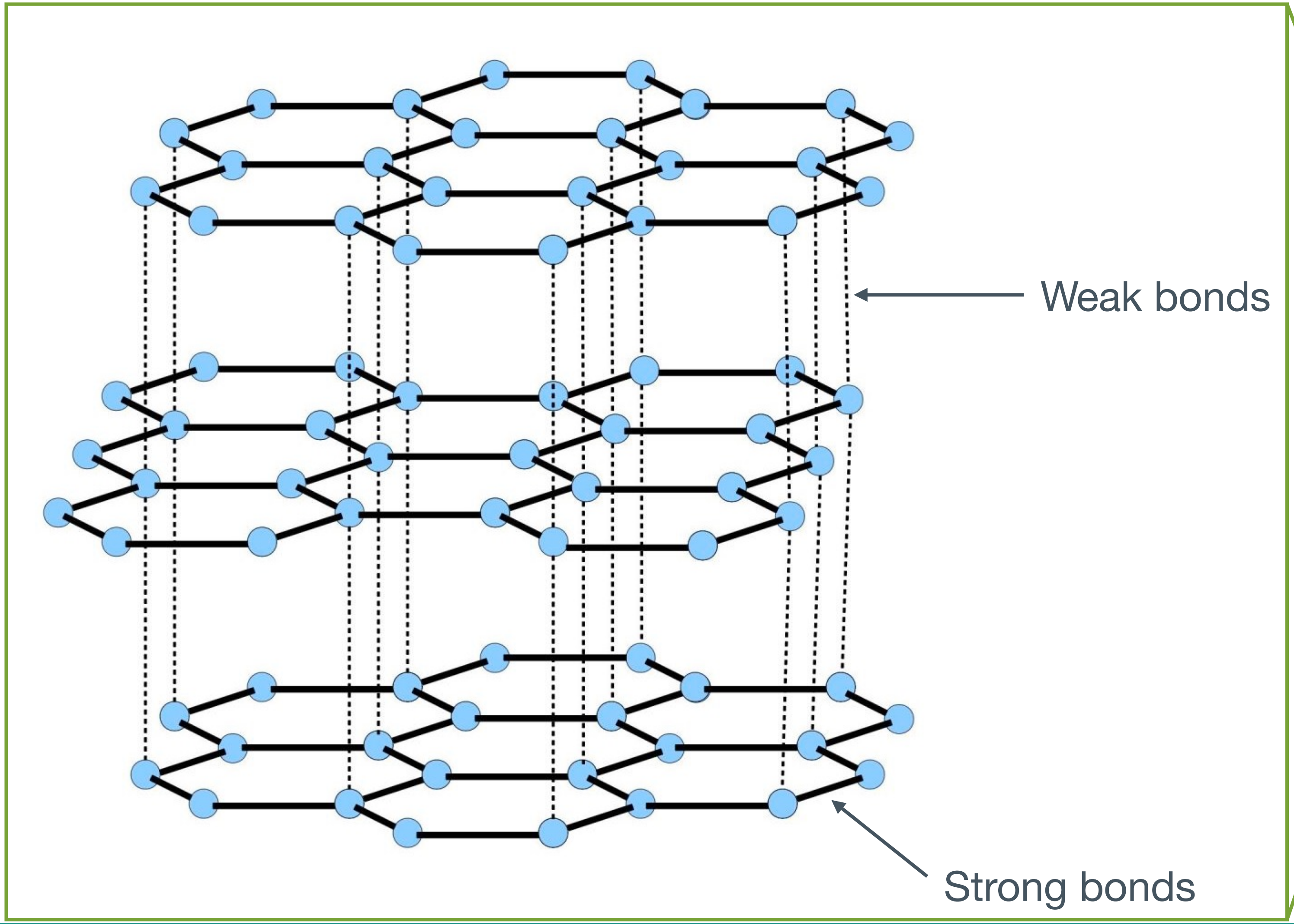


Batteries: Lithium-Ion

Lithium-Ion Batteries

- A rechargeable battery commonly used for portable devices and electric vehicles.
- Developed by John Goodenough, Richard Yazami and Akira Yoshino in 1980.
  - Akira Yoshino is known as the Father of Lithium-Ion Batteries
- Became available to the public in 1991 by Sony and Asahi Kasei.
- Advantages: high energy density, low self-discharge and light weight.

Graphite Chemical Structure (Used as the anode)

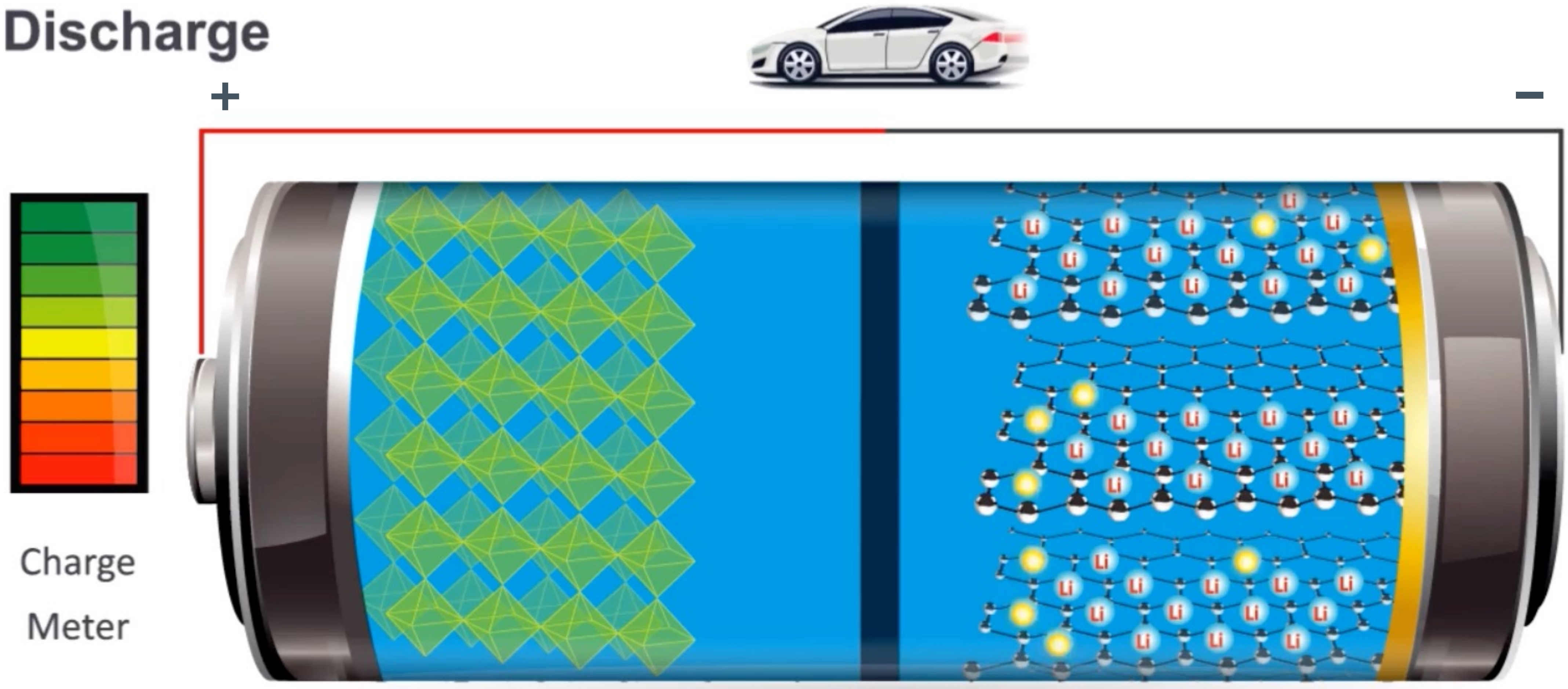


Lithium-Ion Energy Storage

Key Performance Data – European Association for Storage of Energy

Power Range	1 kW – 50 MW
Energy Range	Up to 10 MWh
Discharge Time	10 minutes - 4 hours
Cycle Life	2,000 – 10,000
Life Duration	15 – 20 years
Reaction Time	Milliseconds
Efficiency	90 – 98%
Energy (power) Density	120 – 180 Wh/kg
Applications	Time shifting (residential and commercial buildings); voltage, capacity, and contingency of distribution grids; ancillary services of transmission grids; smoothing and shaping of voltage and frequency of renewable energy generation.

How Lithium-ion Batteries Work



Lithium-Ion Fire Hazard 

Short circuits are when an unintentional circuit forms due to the contact of two components

- Malfunctions are rare, but not impossible.
- There is a small risk of microscopic particles encountering other parts of the battery. This can cause what is called a **short-circuit** in the cell.
- Short-circuits can cause fires
- The failure rate of Li-ion batteries is less than one in a million
- Controls are in place to minimize this effect.

- In 2013, when the the Boeing 787 Dreamliner was first released, aircrafts had on board fires due to the Li-ion batteries electrical issues.
  - What happened? Overheating due to a short circuit from a manufacturing defect
  - Issues were promptly resolved by Boeing and the Federal Aviation Administration

Where Can you Recycle Batteries?

- Non-rechargeable batteries can be recycled any may stores around the city, including:

COMMUNITY natural foods
nourishing our community since 1977

staples

THE HOME DEPOT

MEC

THE SOURCE

BEST BUY

LISTEN UP!

PRINCESS AUTO

UBREAKIFIX

IKEA

RONA

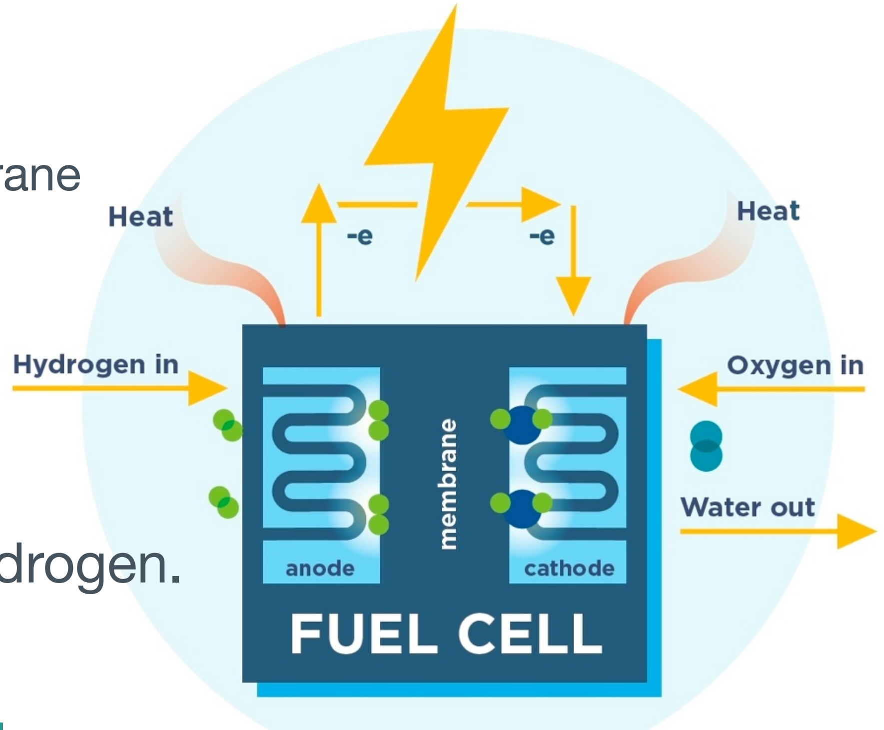
LOWE'S

CANADIAN TIRE

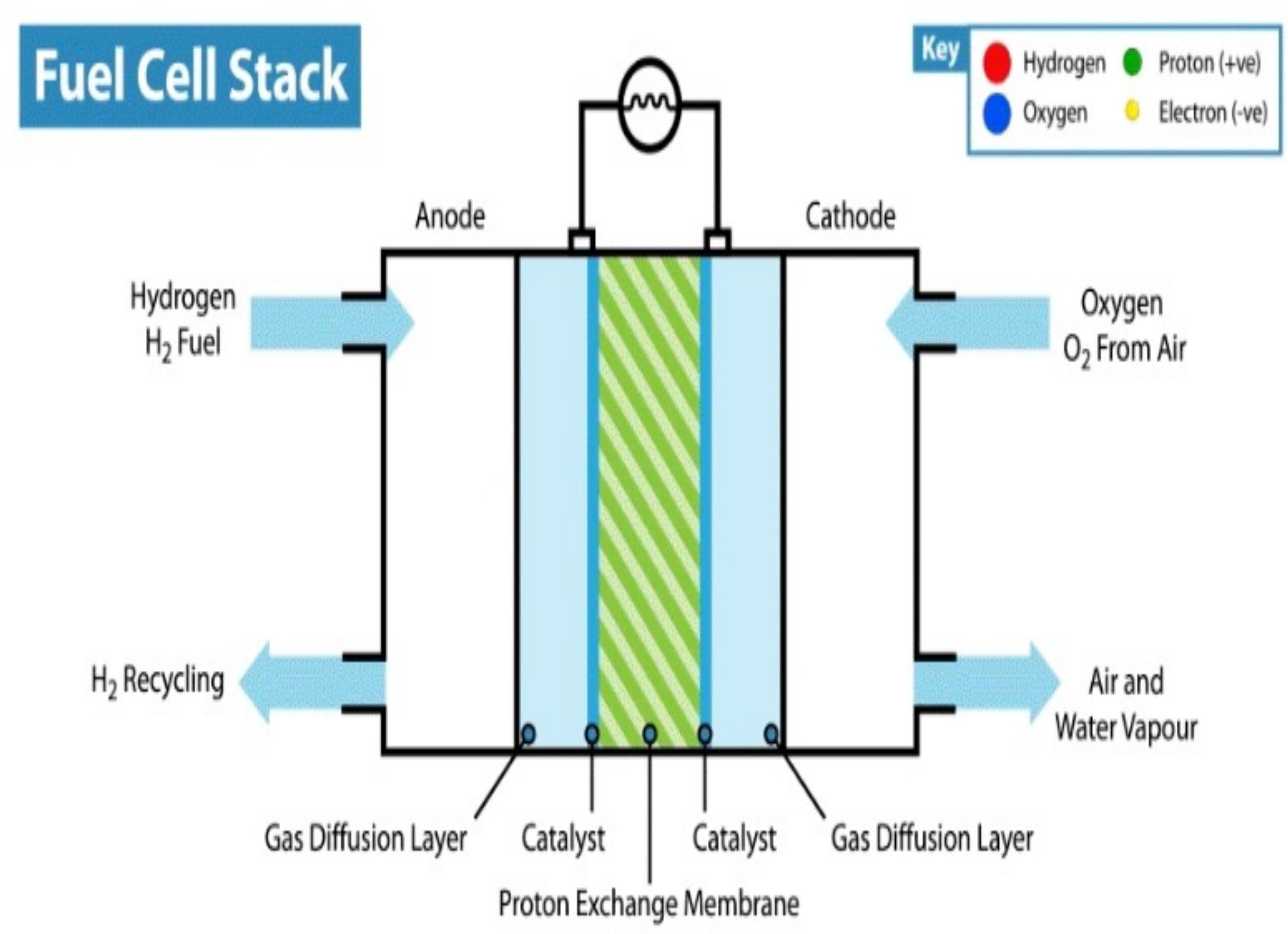
LONDON DRUGS

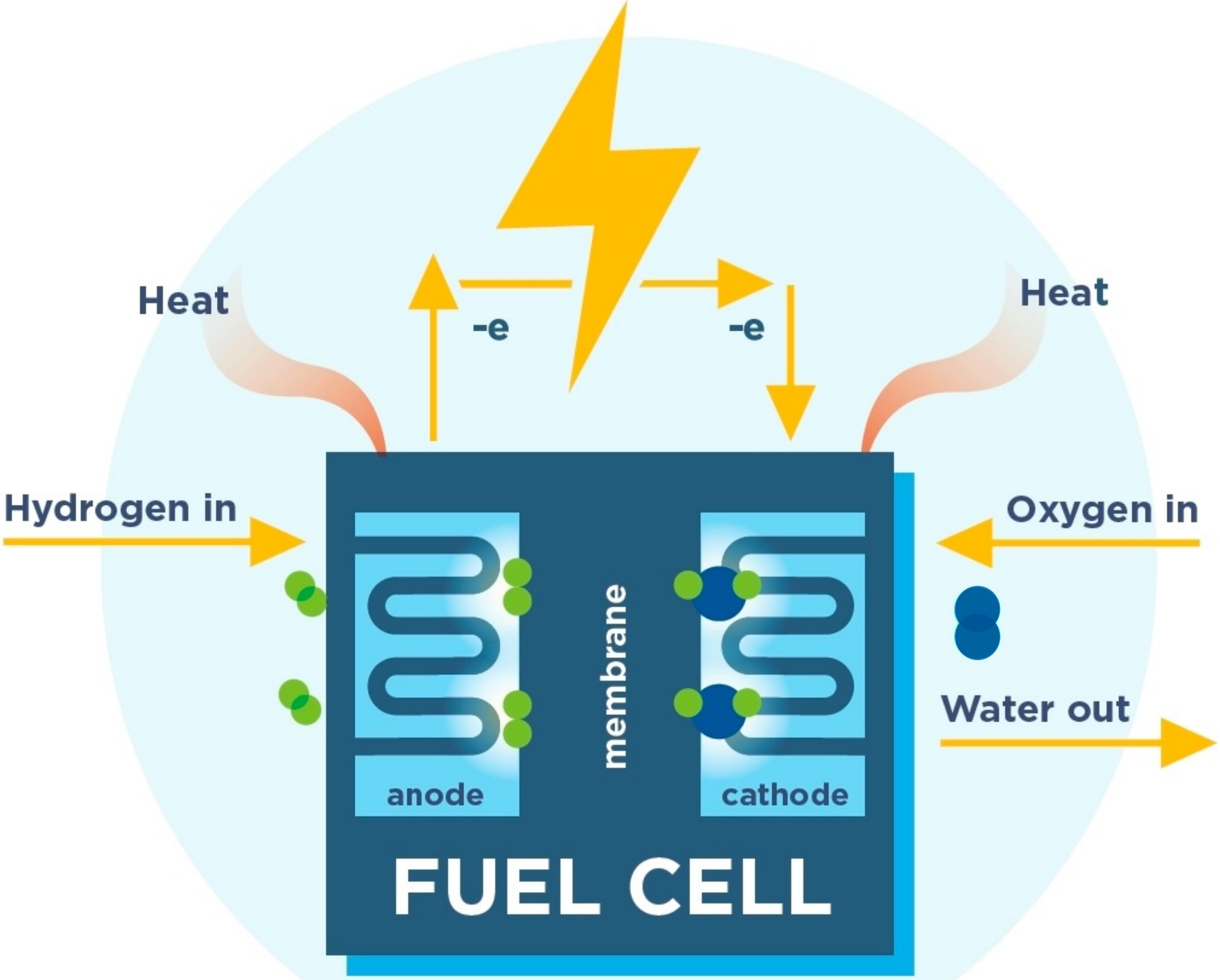
Fuel Cells

- Fuel cells combine hydrogen fuel with oxygen. The products are electricity, heat and water
- The hydrogen used is pressurized and the oxygen (O_2) is extracted from air.
- At the anode:
  - Hydrogen flows in
  - Hydrogen molecules split into electrons and protons
  - Electrons flow through a circuit and protons through the membrane
- At the cathode:
  - Oxygen (from air) flows in
  - Electrons, protons, and oxygen combine to form water
  - Water flows out
- A catalyst is used at the anode to split the hydrogen
- The fuel can be operated in reverse to store energy as hydrogen.



Fuel Cells


Fuel Cell Stack
Key
Hydrogen
Proton (+ve)
Oxygen
Electron (-ve)
Anode
Cathode
Hydrogen
H_2 Fuel
Oxygen
O_2 From Air
H_2 Recycling
Air and
Water Vapour
Gas Diffusion Layer
Catalyst
Catalyst
Gas Diffusion Layer
Proton Exchange Membrane

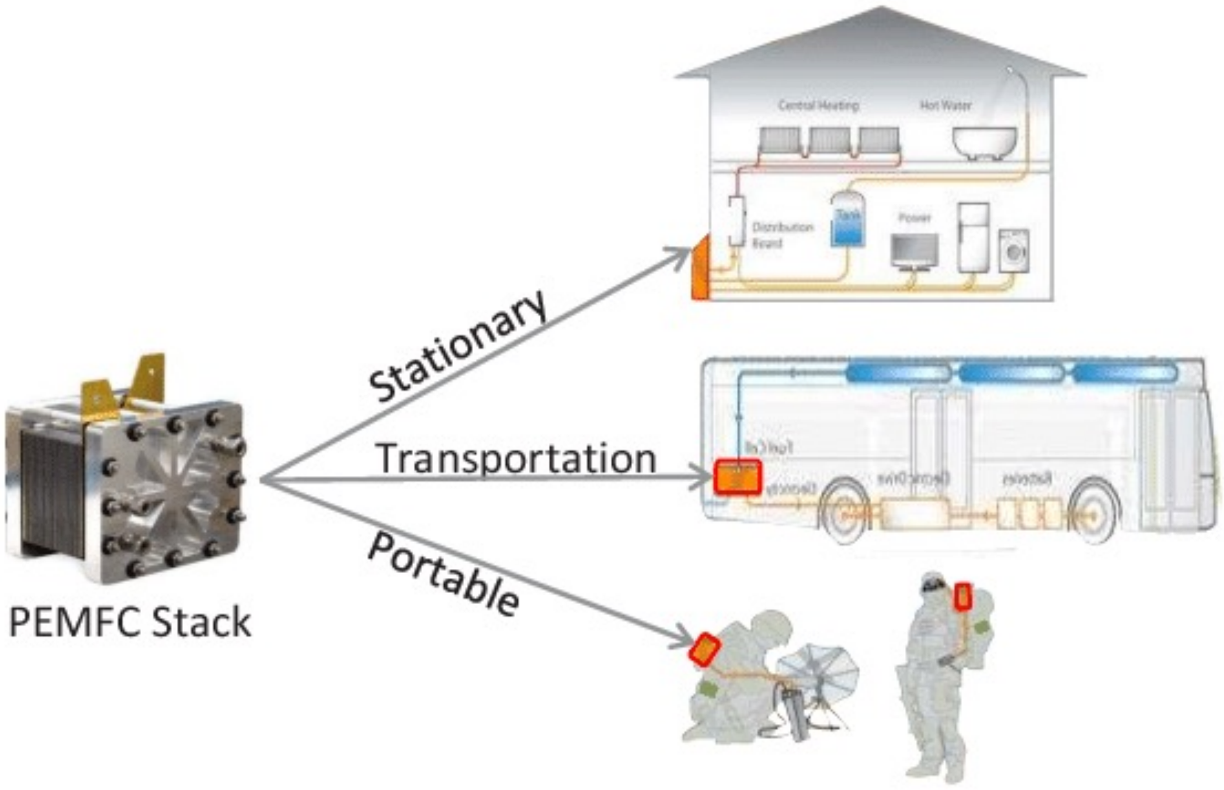


Hydrogen

Oxygen

$$H_2 \rightarrow 2H^+ + 2e^- \qquad O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$$

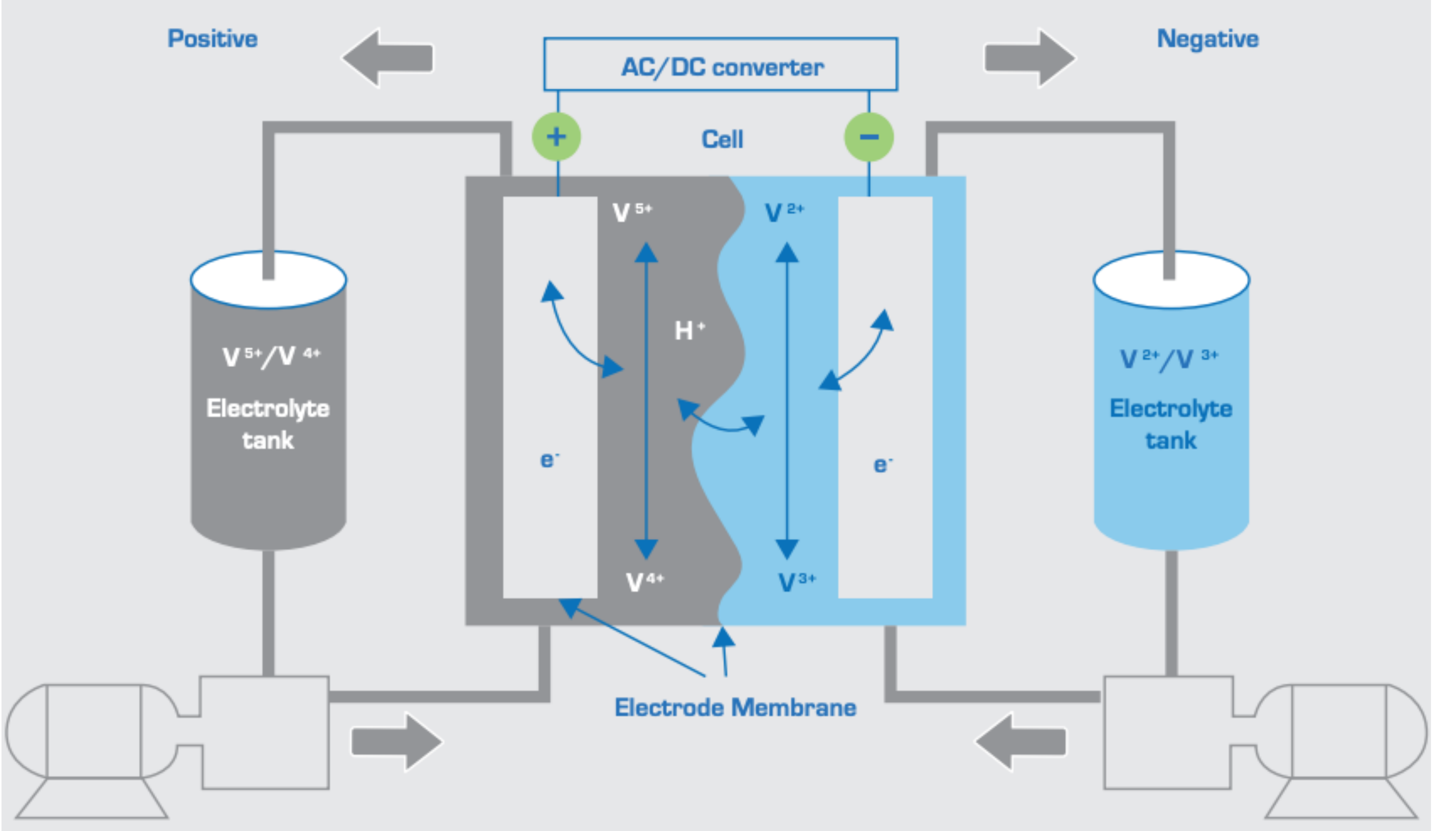
Fuel Cell Applications



- Proton Exchange Membrane (PEM) Fuel Cells are used in cars, as a portable power source, and backup power to offices
- PEM has a high energy-to-weight ratio, and a quick start-up time
- Efficiency is 50%
- Water is the byproduct

Types of Fuel Cells

Type of Fuel Cell	Applications	Efficiency	Limitations	Cell Temperature
Proton Exchange Membrane (PEM)	Portable, stationary, automotive	35–60% efficient	Expensive catalyst; needs chemical grade fuel; complex heat and water control	70-90°C
Molten Carbonate (MCFC)	Large power generation	45–50% efficient	High heat causes corrosion, long start-up, short life	650°C
Phosphoric Acid (PAFC)	Medium to large power generation	40% efficient	Low efficiency; limited service life; expensive catalyst	120-180°C
Solid Oxide (SOFC)	Medium to large power generation	60% efficient	High heat causes corrosion, long start-up, short life	700-950°C



Flow Batteries

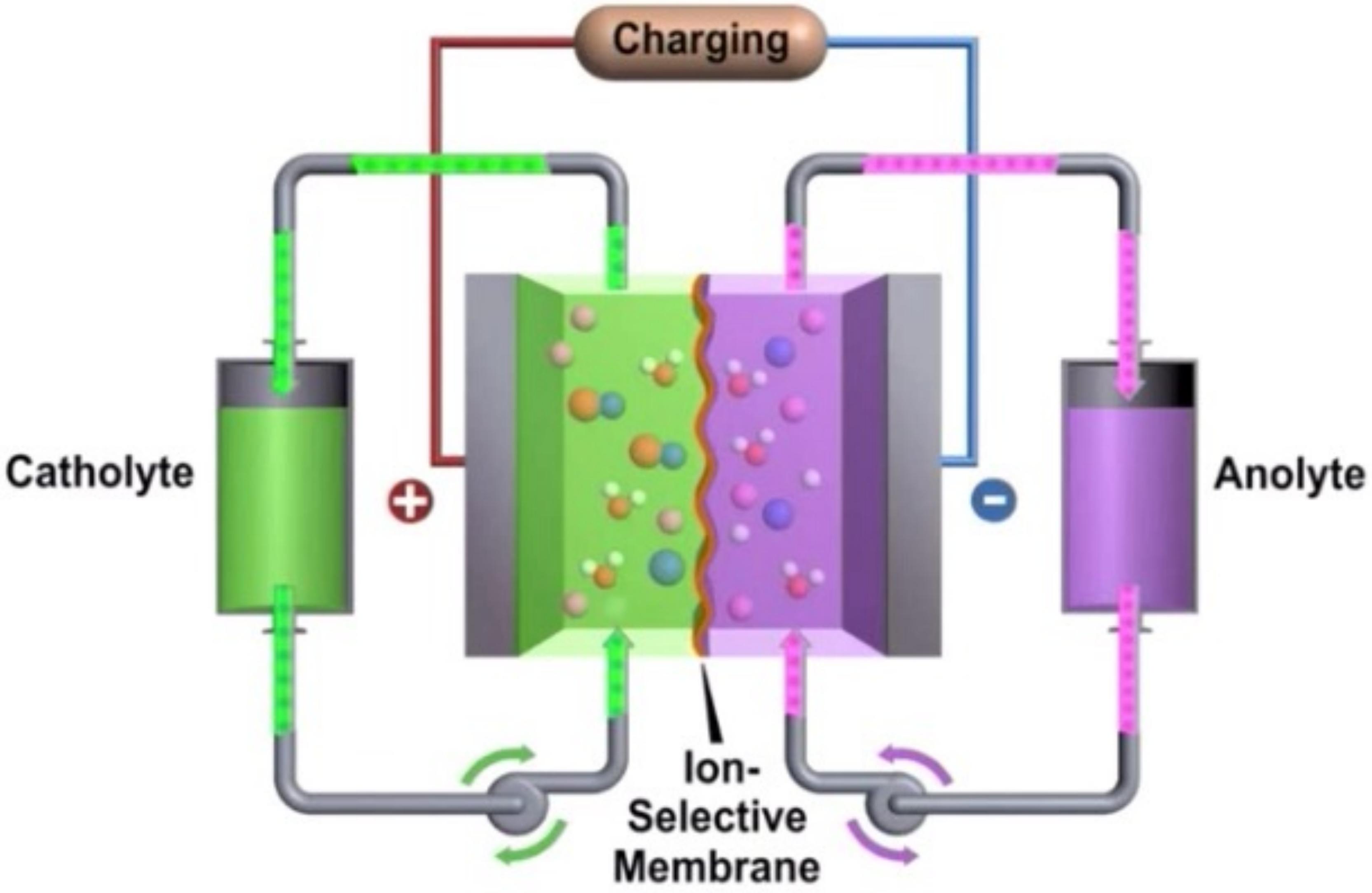
- Developed in 1970 by NASA
- A rechargeable battery composed of two liquid electrolytes separated by a membrane
- The energy capacity is dependent on the size of the tanks, and the volume of the electrolyte
  - Increase the capacity by increasing the size of the storage tank
- Electrolyte combinations:
  - Vanadium/vanadium
  - Iron/chromium

Flow Batteries

Key Performance Data – European Association for Storage of Energy

Power Range	kW - MW
Energy Range	100 kWh – MWh
Discharge Time	hours
Cycle Life	>12,000
Life Duration	10 – 20 years
Reaction Time	Milliseconds
Efficiency	70 – 75%
Energy (power) Density	10 – 25 Wh/liter
Applications	Energy storage, peak shaving, energy time shifting

Flow Battery Video



Source of Vanadium (V)

- Vanadium is used as the electrolyte for flow batteries
- Vanadium is mined in China, Russia and South America
- 90% of mined vanadium is used as an additive to strengthen steel
- The wasted vanadium can be recycled and used in flow batteries
- Alberta oil sands may be a source of vanadium.

Advantages and Disadvantages of Chemical Energy Storage

ADVANTAGES

- Combustive chemical reactions can be converted into energy
- Chemical energy can be stored for future use
- High energy density
- Cost is decreasing
- Lead-acid batteries are a mature technology
- High energy efficiency:
    - Conventional battery – 60-70%
    - Advanced battery – 75-85%

DISADVANTAGES

- Depending on the type of chemical energy storage used, self discharging may be an issue
- Lithium-ion batteries have a fire hazard
- Depth of discharge limits total usable energy

Chemical Energy Storage in Alberta

- Project: Ghost Pine Battery Energy Storage System
- Developer: NextEra Energy
- Location: Kneehills County, Alberta
- Description: 30MW energy storage project located at the existing 82MW Ghost Pine Wind Farm to store excess energy for times of low resources

Thank you!

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