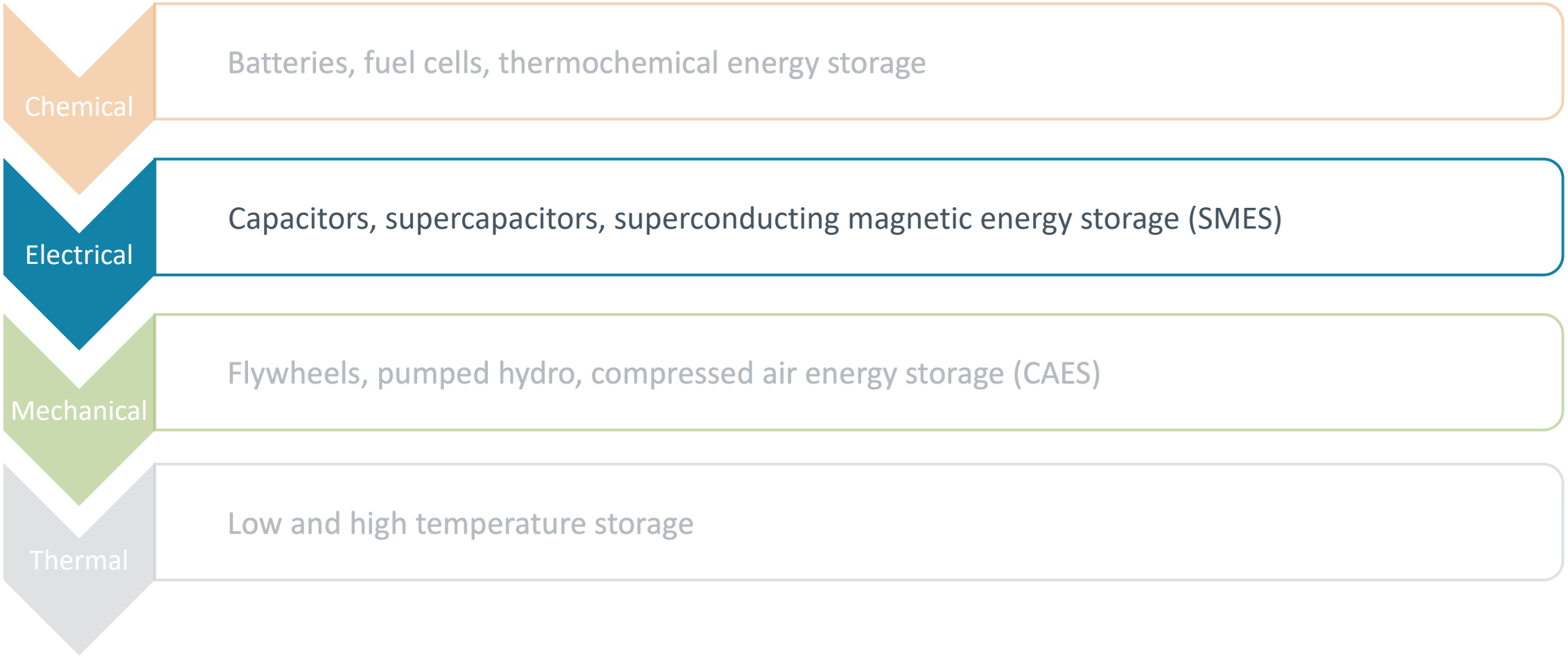
Electrical Energy Storage

Capacitors, Supercapacitors, SMES

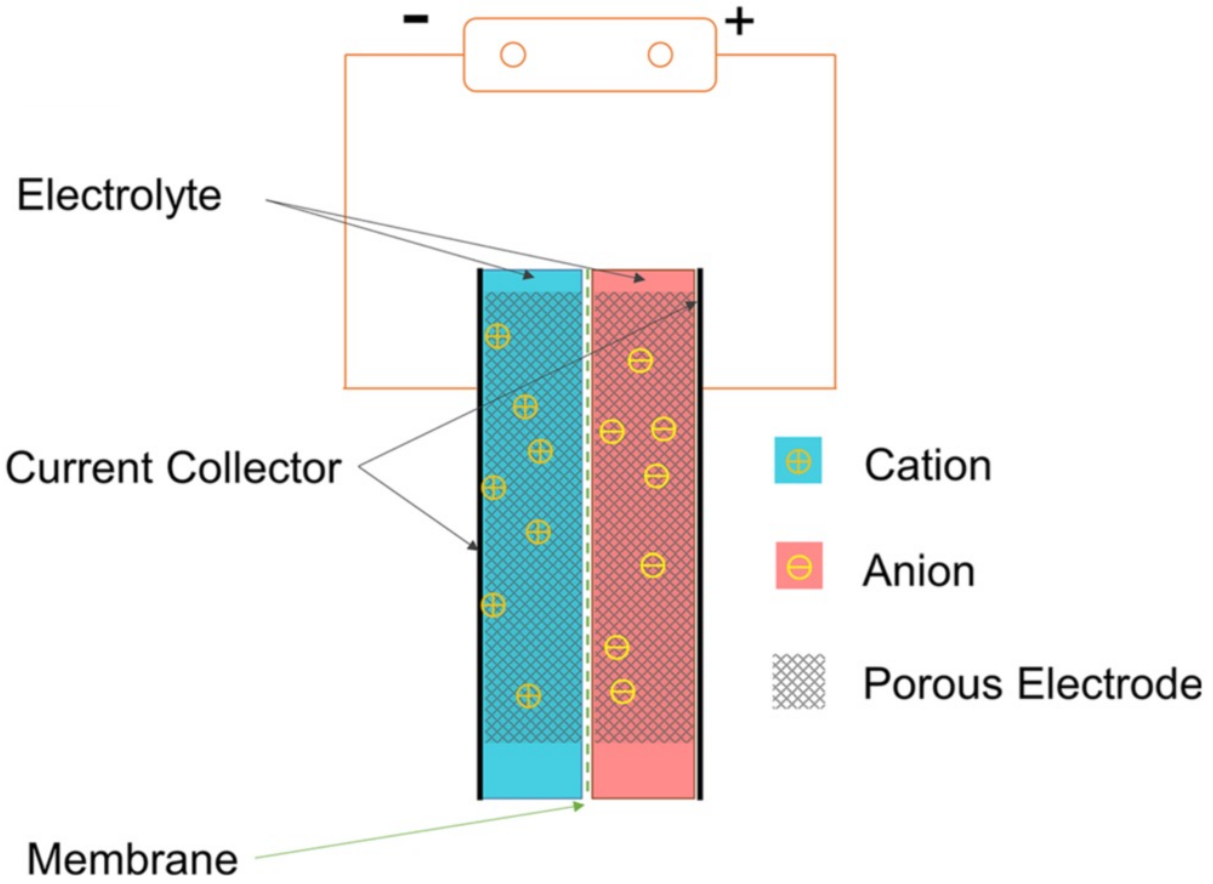
Recommended for grades 7-12

Electrical Energy Storage



Supercapacitors

- European Association for Storage of Energy definition:
  - "An energy storage system based on electrostatic effects that occur between **two carbon electrodes** with high specific surface areas per volume"
- Supercapacitors are also called Electrochemical Double Layer Capacitor (EDLC)
- EDLC's store more energy than conventional capacitors
- Operating temperature: **-40°C to 70 °C**



Dielectric: A non-conducting substance. One that transmits an electric charge without conducting it. An insulator.

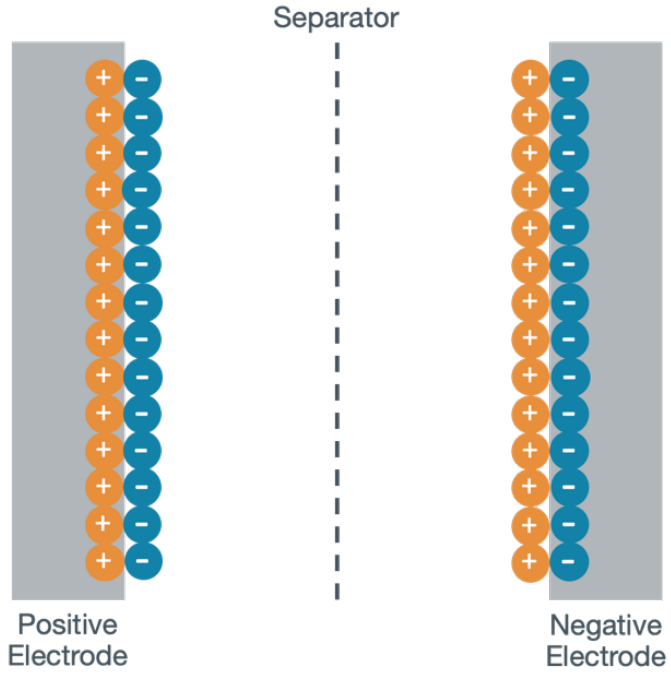
Supercapacitor Components:
2 Carbon electrodes
1 Electrolyte
1 Dielectric Membrane

Supercapacitors Basics

- Capacitors are like batteries – they both store **electrical energy**
  - Batteries use chemical reactions to produce electrons at one terminal and absorb the electrons at the other terminal
- Capacitors do not have two terminals. Instead, they have **two plates**
- Capacitors do not produce electrons like batteries, rather, they **store already existing electrons**
- The two plates are separated by a dielectric material (electrical insulator):
  - Dielectric materials are mica, ceramic, cellulose, porcelain, Mylar, Teflon, and air
- Capacitance is the storage potential of a capacitor, and is measured in Farads

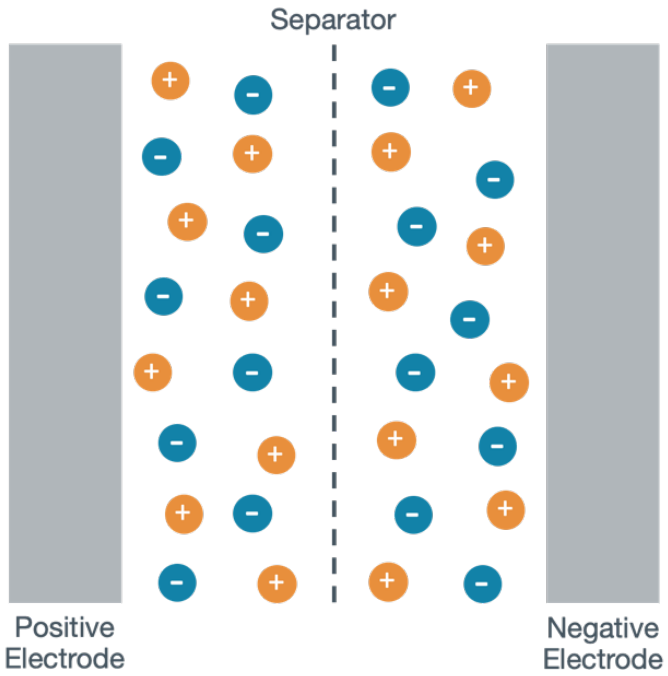
How do Supercapacitors Work?

- Capacitors store energy based on the **electrostatic effects** between the two carbon electrodes
- When charged, cations (+) accumulate at the negative electrode, and anions (-) accumulate at the positive electrode
  - This forms the **Helmholtz-Layer (creating two distinct charged "layers")**



Charged

Helmholtz-Layer

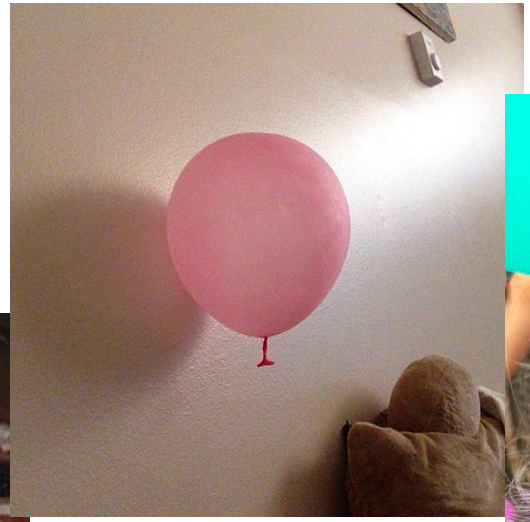


Discharged

Non-Helmholtz-Layer

Electrostatic Effect

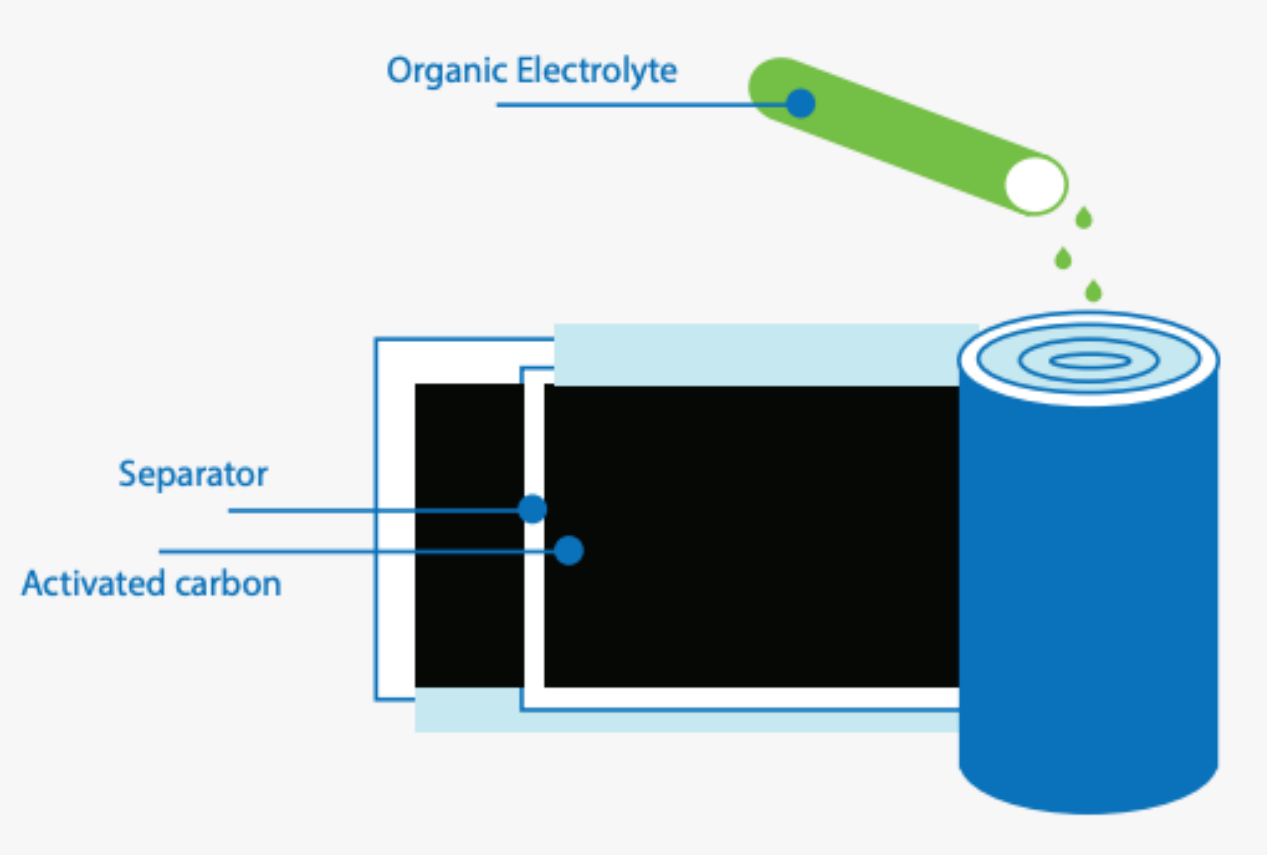
- Electrostatic effect is the force electric charges exert on one another.
  - Coulomb's Law
- It is the buildup of an electrical charge on a surface
- When two objects are rubbed together, the electrons are transferred between each other
- Examples:

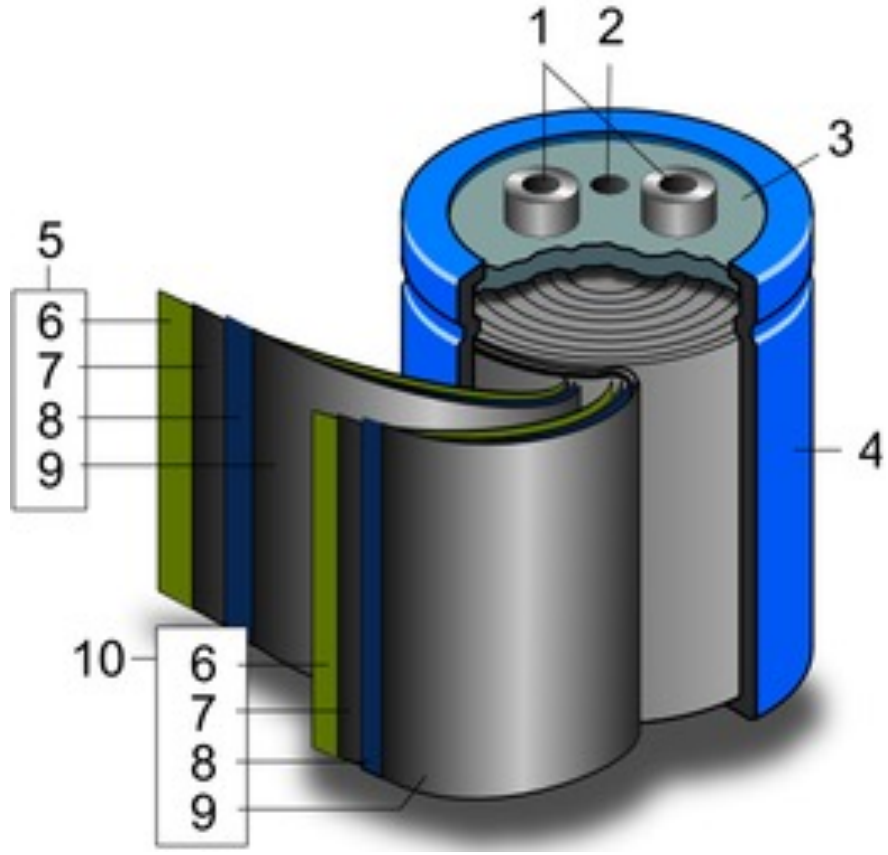


ACTIVITY: Electrostatic Effect

- **Materials:**
  - Balloon
  - Water faucet
- **Instructions:**
  - Blow up the balloon
  - Turn tap on so there is a light stream
  - Rub the balloon against something (try different surfaces and materials)
  - Hold the balloon near the water stream. What happens?

Components of a Supercapacitor





1. Terminals
2. Safety vent
3. Sealing disc
4. Aluminum can
5. Positive pole
6. Separator
7. Carbon electrode
8. Collector
9. Carbon electrode
10. Negative pole

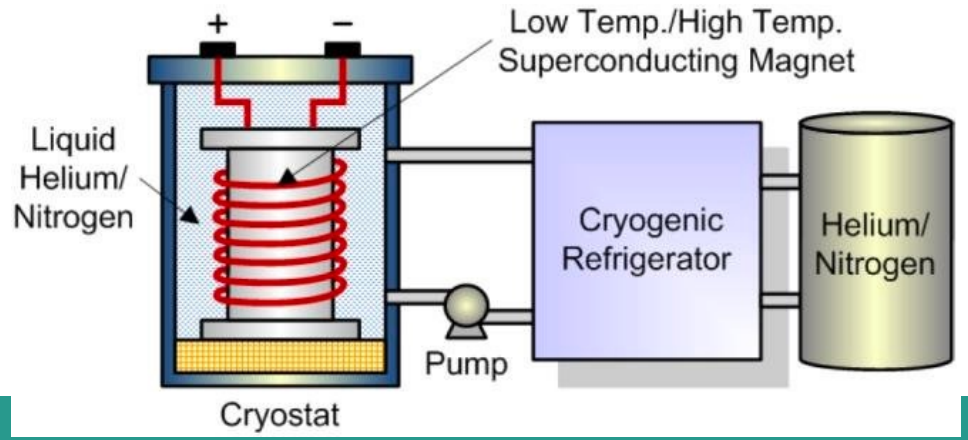
Supercapacitors

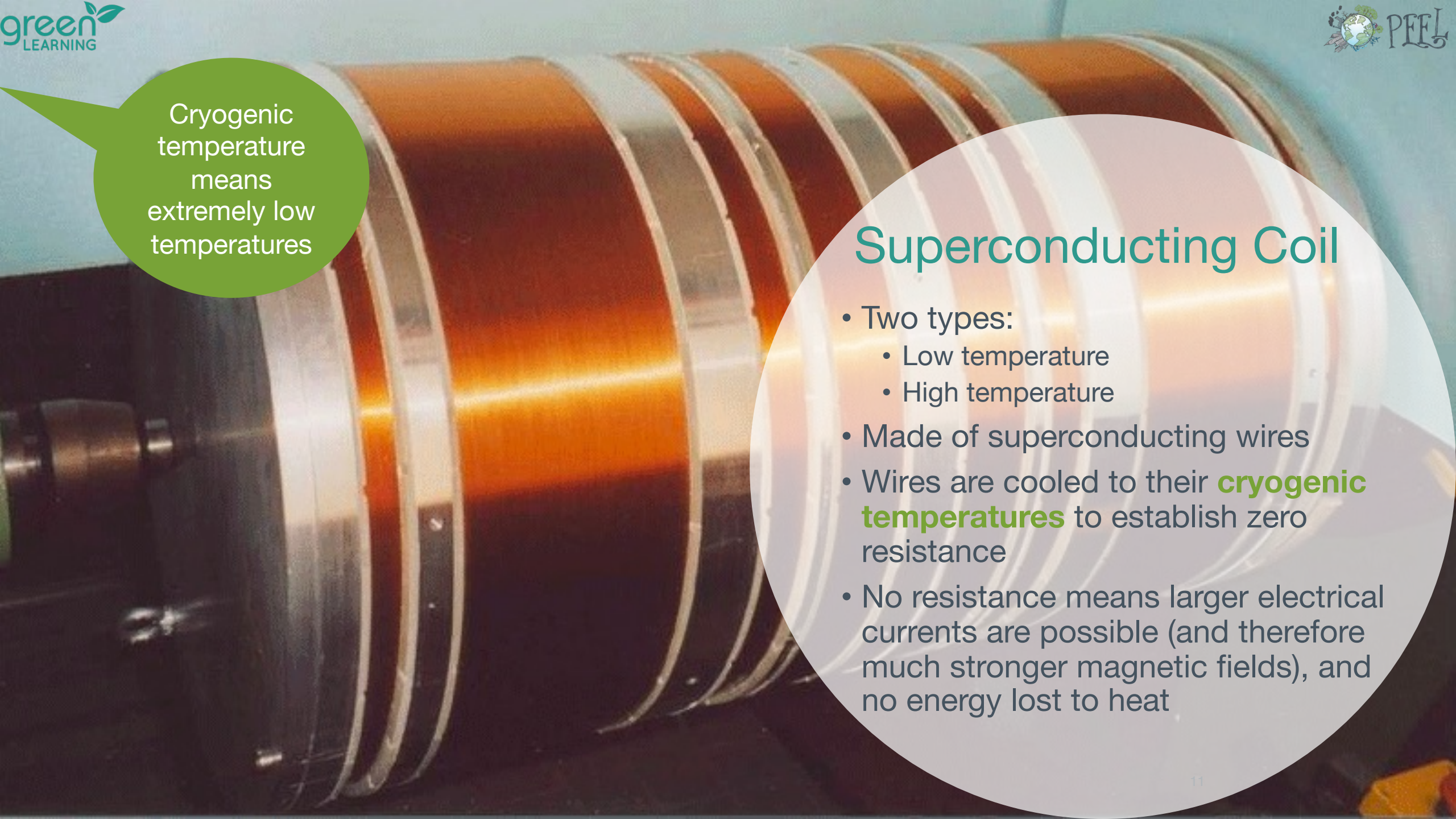
Key Performance Data – European Association for Storage of Energy

Power Range	MW's
Energy Range	kWh's
Discharge Time	Seconds to minutes
Cycle Life	1 million cycles
Life Duration	10 years at room temperature
Reaction Time	5 milliseconds
Efficiency	90%
Applications	Backup power, load balancing, engine start/acceleration for hybrid vehicles, energy storage for intermittent renewable energy

Superconducting Magnetic Energy Storage (SMES)

- SMES uses **superconducting coils** to store energy in the magnetic field
- What are superconductors?
  - A material that will create electricity with little to no resistance below the critical temperature.
- No resistance is important because it means no energy losses
- When a superconductor is charged, the electrical current stored will flow through the closed superconducting coils indefinitely, until acted upon by another force.
- Unlike other storage technologies, SMES stores the energy in its electrical form and does not require further conversion
- The superconducting coil prevents the energy energy from dissipating within milliseconds





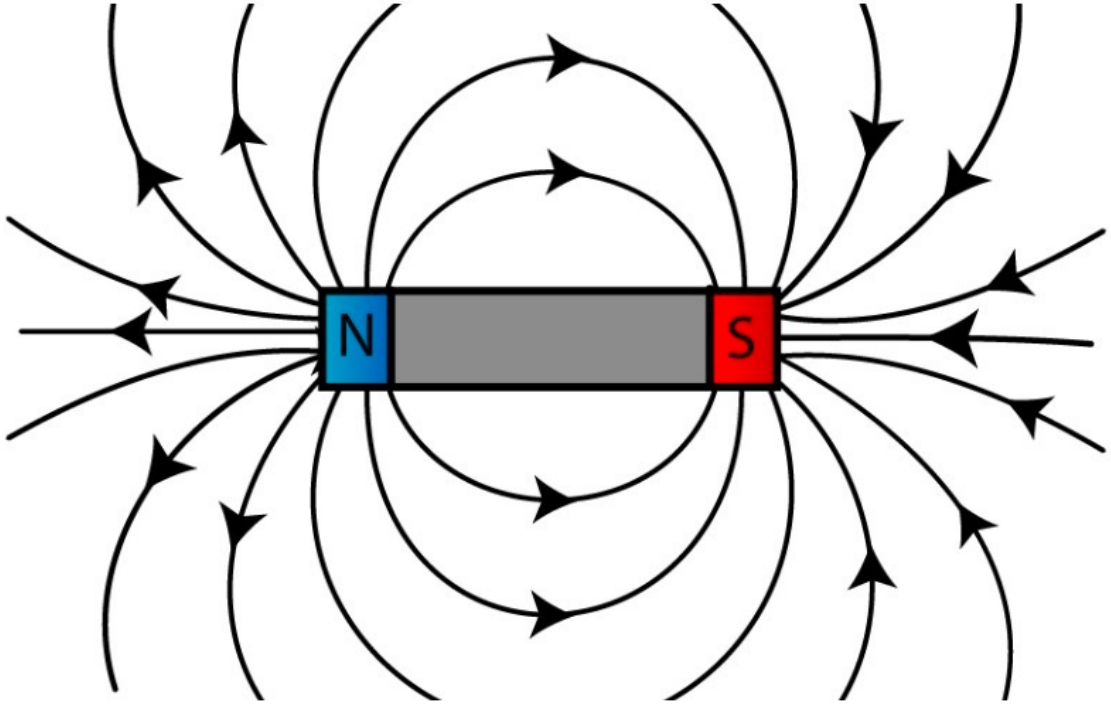
Cryogenic temperature means extremely low temperatures

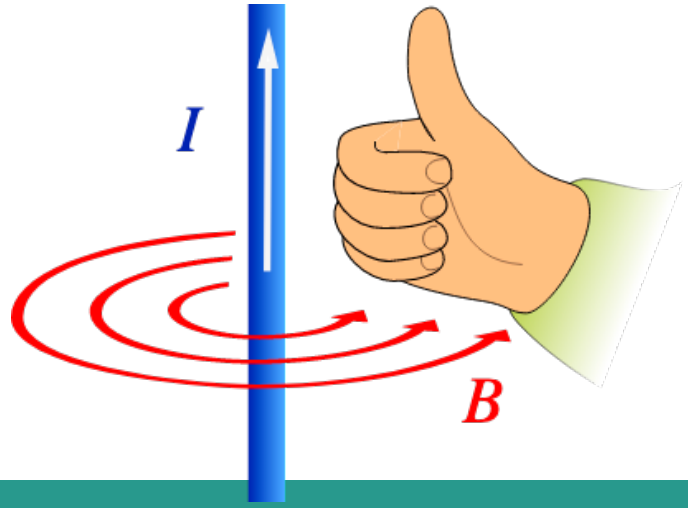
Superconducting Coil

- Two types:
  - Low temperature
  - High temperature
- Made of superconducting wires
- Wires are cooled to their **cryogenic temperatures** to establish zero resistance
- No resistance means larger electrical currents are possible (and therefore much stronger magnetic fields), and no energy lost to heat

Magnetic Field (B)

- A **vector field** with **field line** notation
- A vector field is described by its magnitude (strength) and direction
- These lines never cross and point continuously from north to south (a closed loop)
- SI units: tesla (T)
  - The force applied to a moving charge due to the field
- The electric current (*I*) and magnetic field (*B*) are related by the *right-hand rule*





Your thumb shows the direction of the electric current and your fingers point in the direction of the magnetic field. If you know one, you can figure out the other.

SMES

Key Performance Data

Power Range	0.1 – 10 MW
Discharge Time	Milliseconds – 8 seconds
Cycle Life	Unlimited
Life Duration	20 – 30 years
Efficiency	95%
Applications	Uninterruptible Power Supply

Advantages and Disadvantages of Electrical Energy Storage

ADVANTAGES	DISADVANTAGES
• High energy efficiency: • Capacitor and SMES – 90-95% • Fast responding – can respond instantaneously and provides energy for a brief period. • Provides power quality services for times of voltage sags and power outages • Environmentally friendly – does not require chemical reactions or produce toxins	• SMES and supercapacitors are developed but not considered a mature technology • SMES requires large amounts of power to maintain the superconducting temperature • Suitable for short duration power supply only – limited hours in storage • High self-discharge for long periods (10-15%)

Thank you!

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