



PEEL

People for Energy and
Environmental Literacy

Energy Storage 101

Introductory Course on Energy Storage

Recommended for grades 7 – 12

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What is Energy Storage?

You can think of ES as a **very large battery**.

- Energy Storage (ES) stores energy **now** for use **later**
- **There are many technologies used in ES**
- There are multiple uses for energy storage
- ES can be connected directly to **the transmission or distribution electricity grid** – it can ‘generate’ electricity or ‘consume’ electricity
- The cost of ES has decreased over the years

The Electricity Grid: The electricity grid is the transmission system and distribution system. The electricity grid transmits our electricity from power stations to our homes.

What is Energy Storage?



Energy storage allows you to store energy for a later time



Most common forms of energy storage is pumped hydroelectric storage (PHES).



Another common form of energy storage, of course, is your average battery.

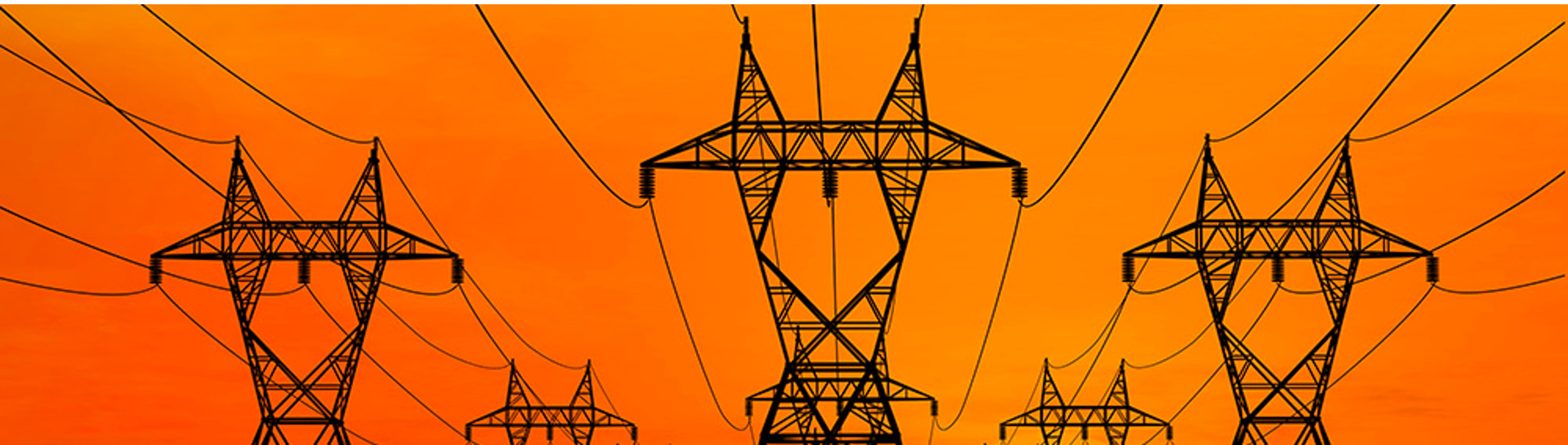
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Our lives are centered around energy storage



The Electrical Grid

- Engineering World – Electrical Grid 101: All you need to know!
 - 3 min, 46 sec
 - <https://www.youtube.com/watch?v=nbPmsBmo03Y>

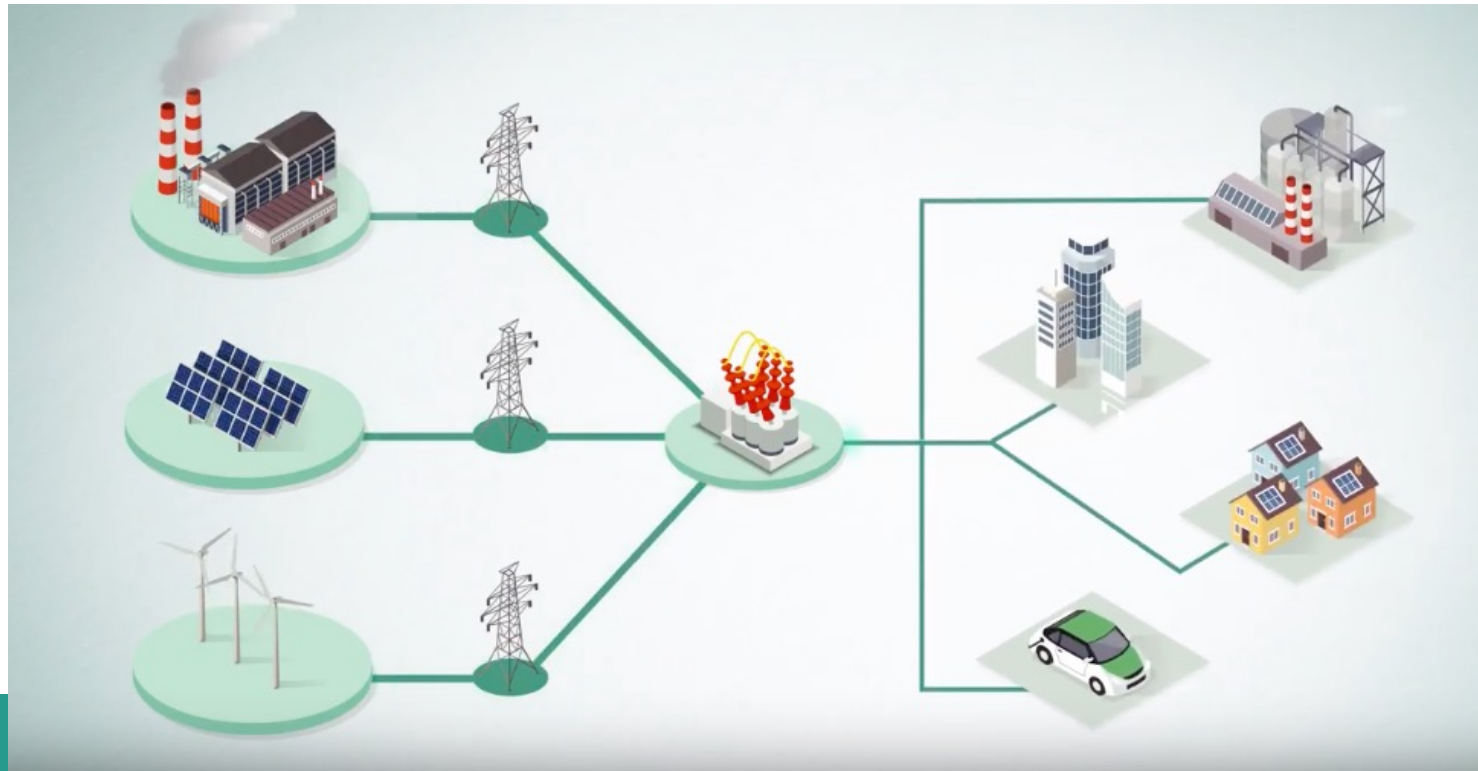


- Energy storage helps to mitigate problems we face with energy in terms of cost and availability
- Energy Storage allows us to **store energy now** and **use later**.
 - For times of low generation capacity, and for times of high cost
- Energy generators can store excess energy for later use
- Customers can purchase energy during off peak hours and sell during on peak hours to save money

Why Energy Storage?

Energy Storage Video

- Black and Veatch – Battery Storage Basics
 - 4 minutes, 37 seconds
 - <https://www.youtube.com/watch?v=jcZuG1mmtY8>



Types of 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

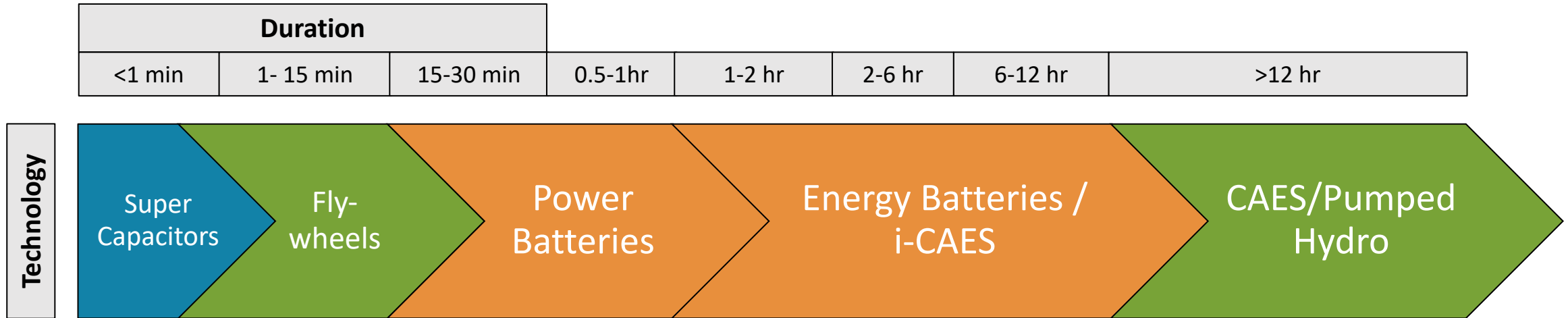
Low and high temperature storage

Types of Energy Storage Technologies

 **ENERGY**
STORAGE

Duration of Technologies

Chemical ES
Electrical ES
Mechanical ES



Chemical Energy Storage

Chemical

Batteries, fuel cells, thermochemical energy storage

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Mechanical

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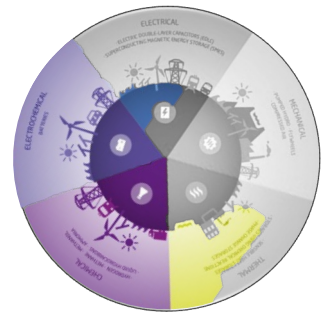
Thermal

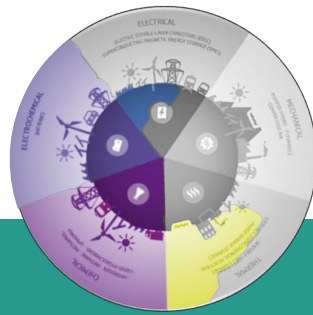
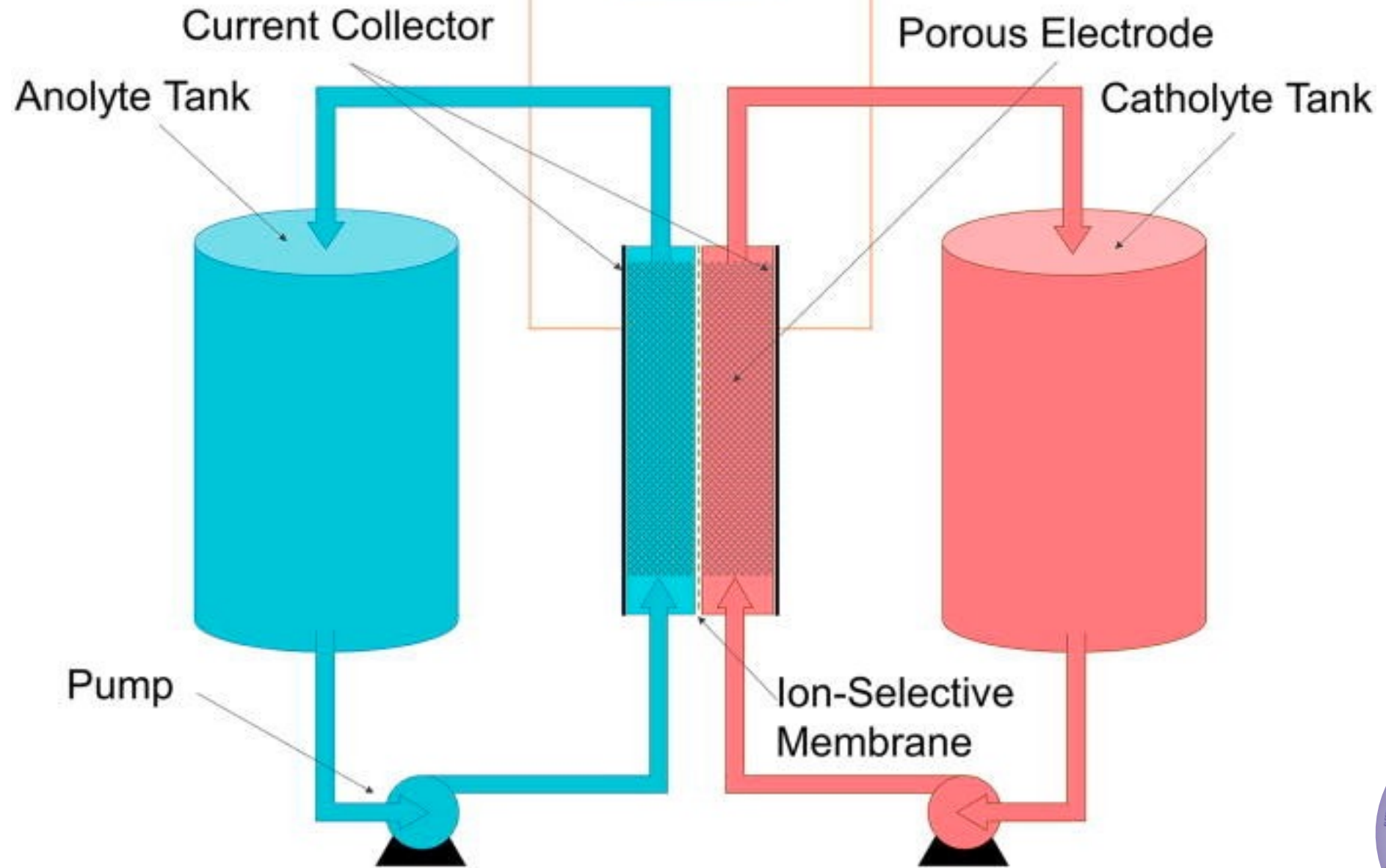
Low and high temperature storage



- 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.

Batteries

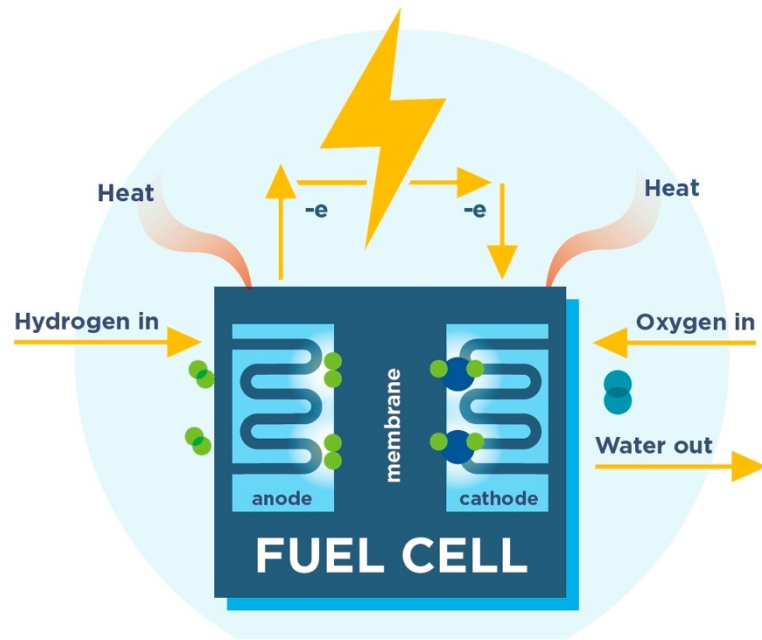




Fuel Cells

- Fuel cells can be used in replace of traditional combustion engines
- Fuel cells typically convert hydrogen-based fuel into electricity
- Components:

- Anode
- Cathode
- Electrolyte Membrane



• 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 flows in
- Electrons, protons, and oxygen combine to form water
- Water flows out



Electrical Energy Storage

Chemical

Batteries, fuel cells, thermochemical energy storage

Electrical

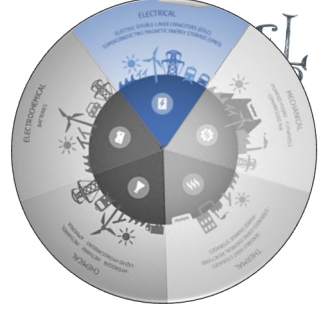
Capacitors, supercapacitors, superconducting magnetic energy storage (SMES)

Mechanical

Flywheels, pumped hydro, compressed air energy storage (CAES)

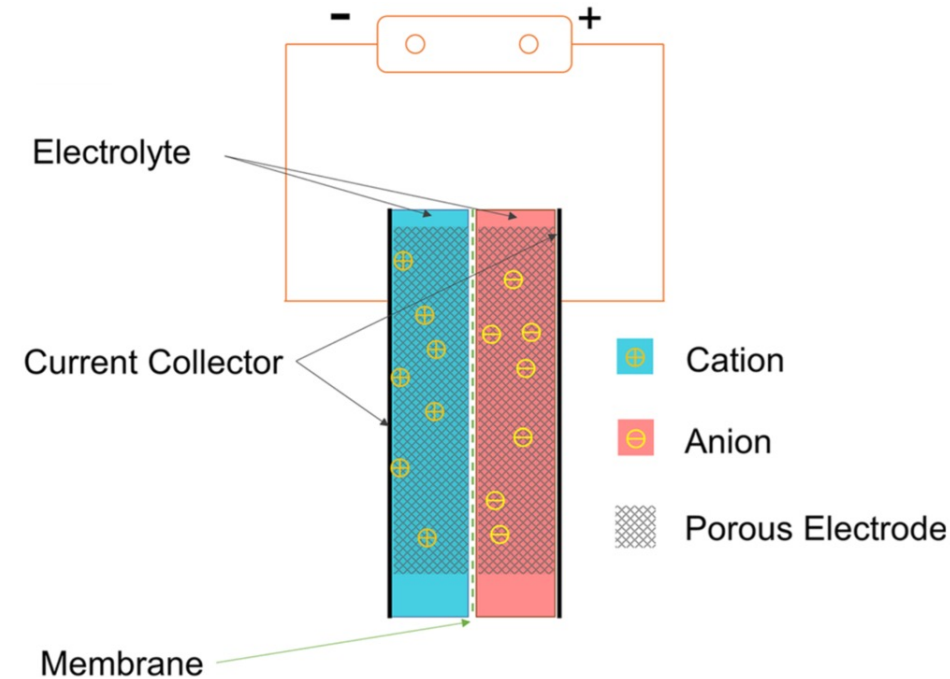
Thermal

Low and high temperature storage



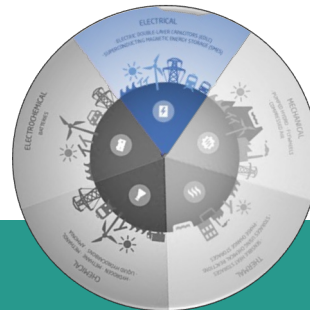
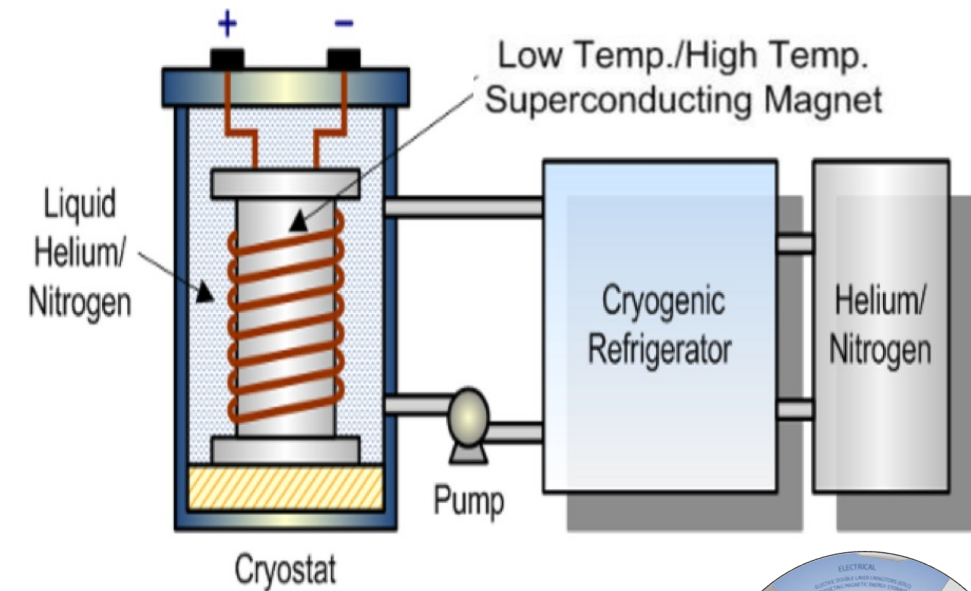
Capacitor and Supercapacitor

- What is a capacitor?
 - “An electronic component that stores electrical charge”¹
 - “A passive electrical element, which accumulates energy in the electric field between the two conducting electrodes”²
- A capacitor is made up of two conducting plates separated by insulating material
- When supplied with a charge, one plate becomes **positively charged** and the other becomes **negatively charged**
- **Capacitance** (the amount of electric charge stored in that capacitor at 1 volt) is measured in Farad (F)
- A supercapacitor has a **higher capacity and energy density** than a conventional capacitor



Superconducting Magnetic Energy Storage (SMES)

- SMES' store energy in the magnetic field induced by **superconducting** coils.
- The superconducting coils are cooled below the superconducting critical temperature
- There is no resistance at this temperature
- Energy is stored in the coil at low temperatures
- The energy current cycles through the coil



Mechanical Energy Storage

Chemical

Batteries, fuel cells, thermochemical energy storage

Electrical

Capacitors, supercapacitors, superconducting magnetic energy storage (SMES)

Mechanical

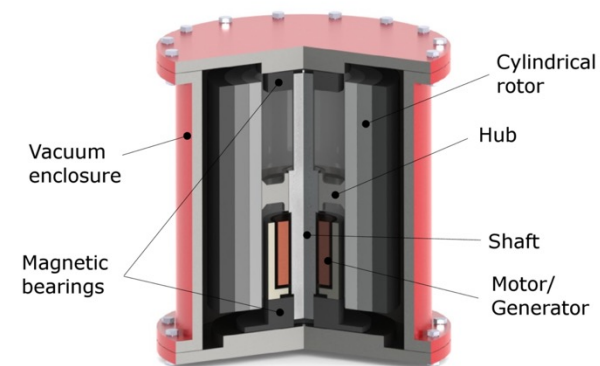
Flywheels, pumped hydro, compressed air energy storage (CAES)

Thermal

Low and high temperature storage

Flywheels

- Flywheels store **rotational energy**
- The energy is contained in the device when rotated at high speeds
- When energy is discharged, the rotational speed decreases
 - Principle of conservation of energy
- Alternatively, when energy is added, the speed increases
- Flywheels have a lifetime of decades with little maintenance

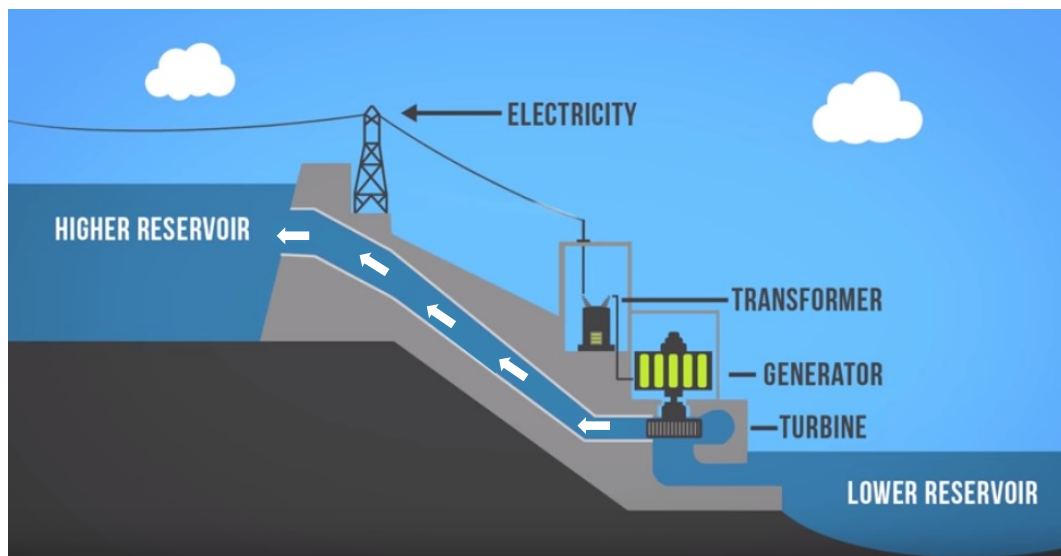


NASA G2
Flywheel!

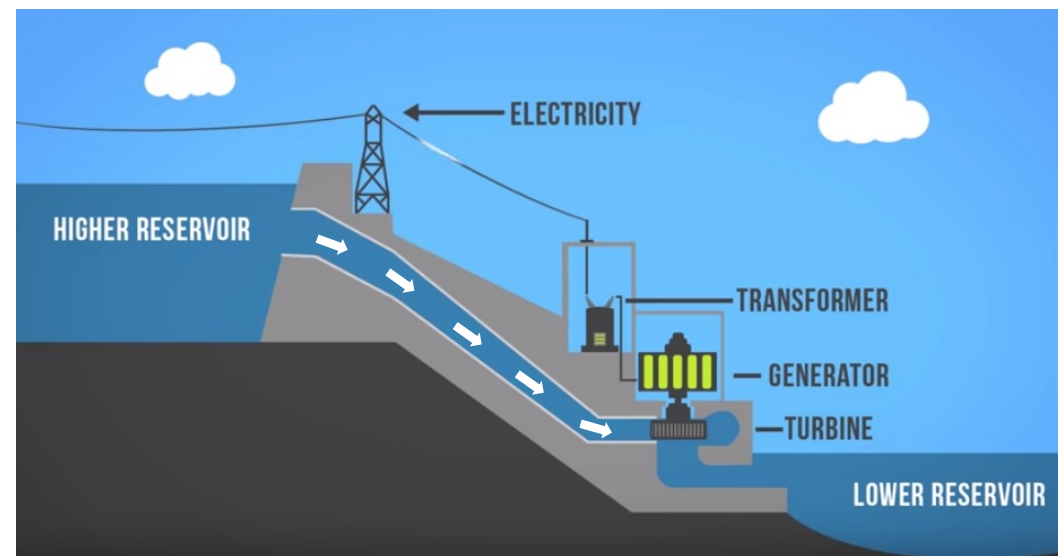
Canadian Flywheel Example:
Ontario Minto Flywheel
2 MW located in Wellington, Ontario
Constructed in 2014.

Pumped Hydro

- 99% of storage technology is pumped hydro
- This technology is mainly used to fill the gaps in the supply and demand requirements, or for arbitrage (buy low, sell high)
- It can store large quantities of energy for days.



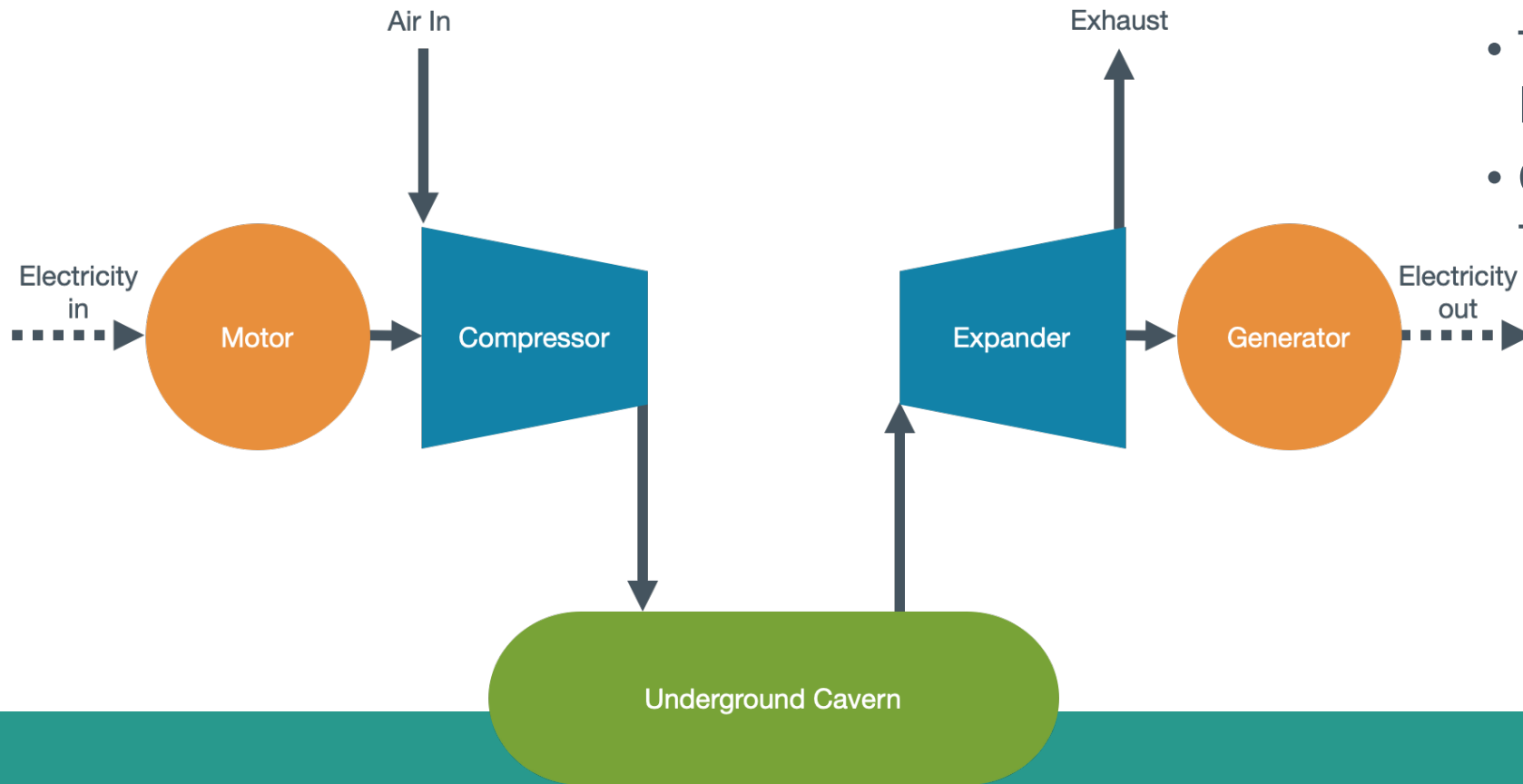
Charge



Discharge

Compressed Air Energy Storage (CAES)

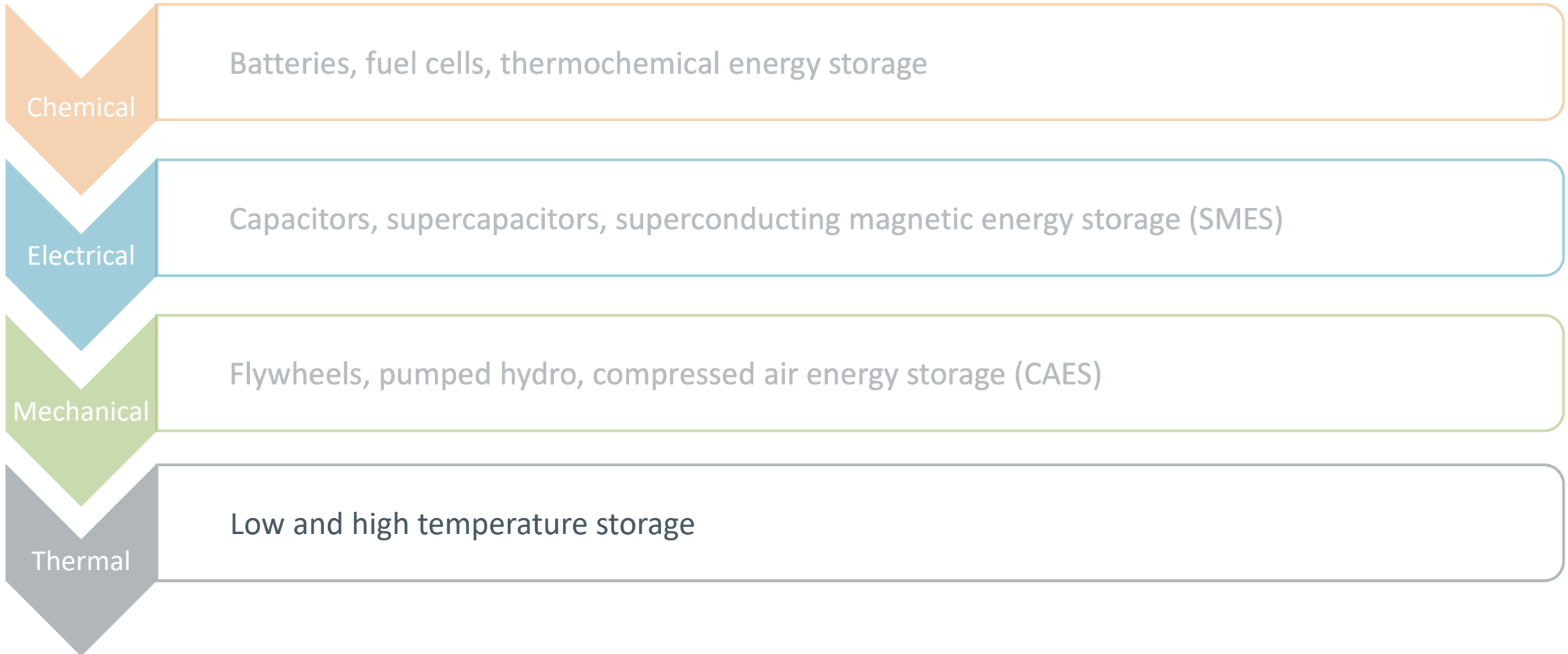
- CAES converts **electrical energy** into **high pressured air**. When the air is released, the air drives a turbine generator, and electricity is produced
- CAES compresses air and stores the pressurized air in an underground cavern



- Two types: Adiabatic CAES and Diabatic CAES
- Ontario has a 1.75 MW CAES facility in Goderich Ontario.



Thermal Energy Storage



Thermal Energy Storage

- Thermal Energy Storage uses extremely high or low temperature to store energy
- Types:
 - **Sensible Heat Storage**
 - “Shifting the temperature of a storage medium without phase change”¹
 - **Phase Change Storage**
 - “Heat storage where a large part of the accumulated heat is released or taken up during the phase change of the heat storage material”²
 - **Chemical Reaction Storage**
 - Dependent on the heat released or absorbed through chemical reactions.



Molten salt storage tanks at the Solana Generating Station in Arizona, USA



Benefit of Energy Storage

Energy storage moves energy

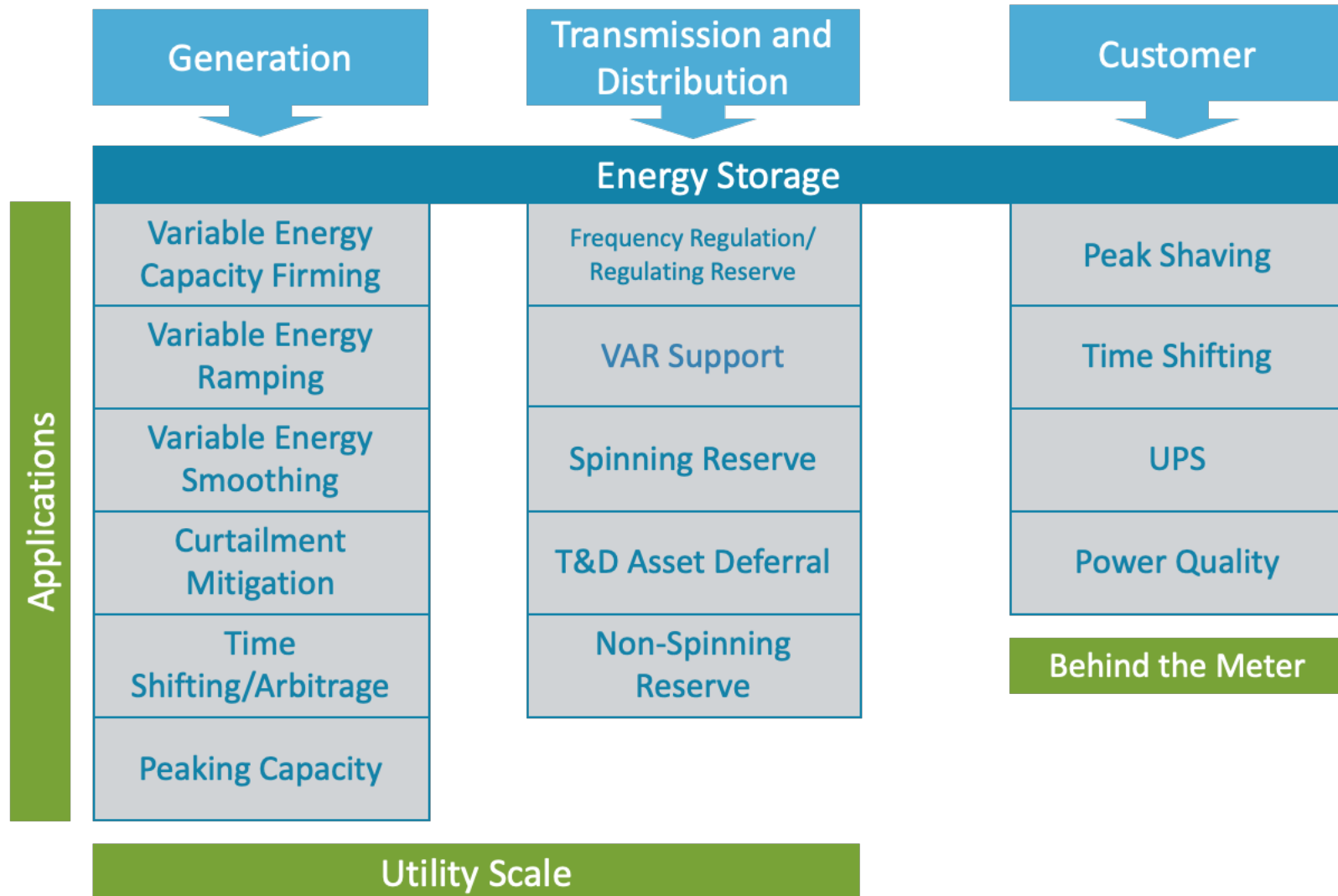
from a time when:

- you don't need the energy,
- you don't want the energy, or
- you cannot take the energy

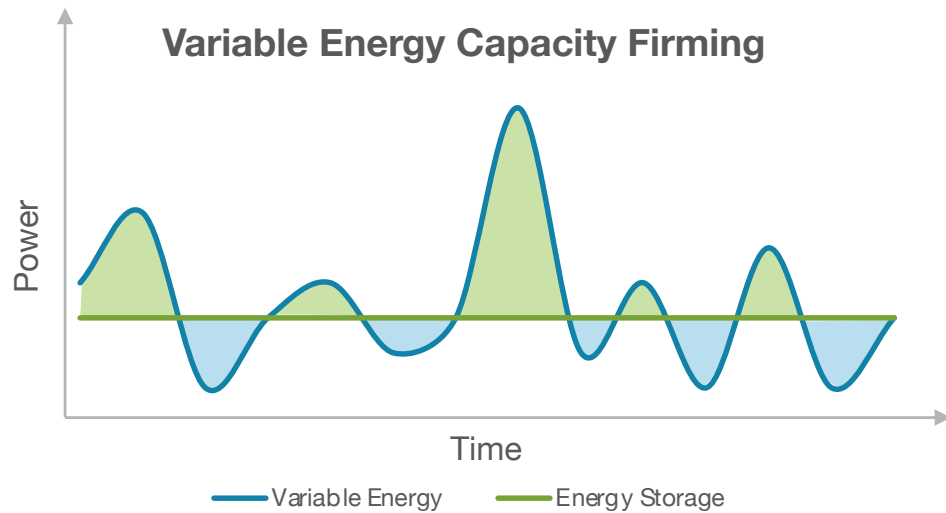
to a time when:

- you need the energy, or
- you want energy, or
- can take the energy.

Fifteen services offered by energy storage

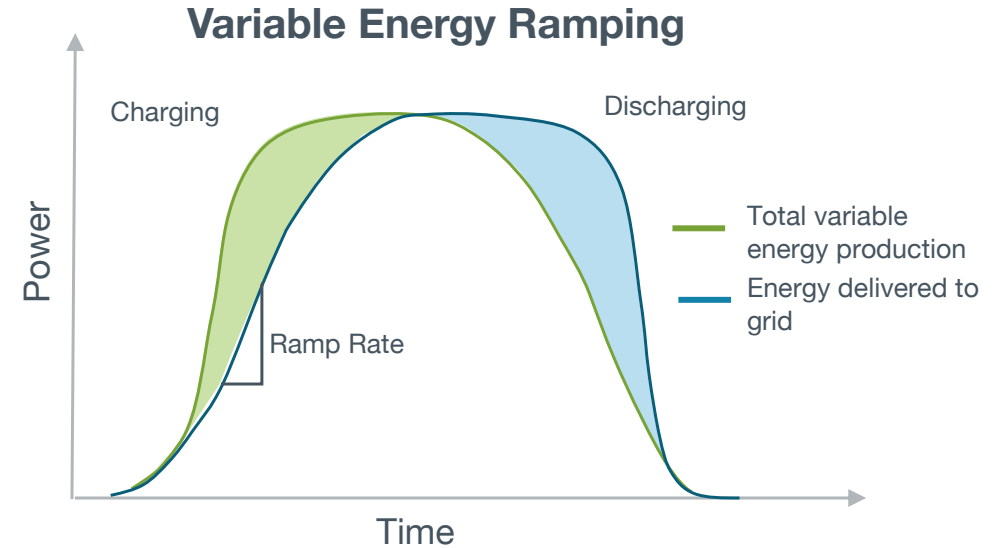


Only three (3) services are used for renewable energy!

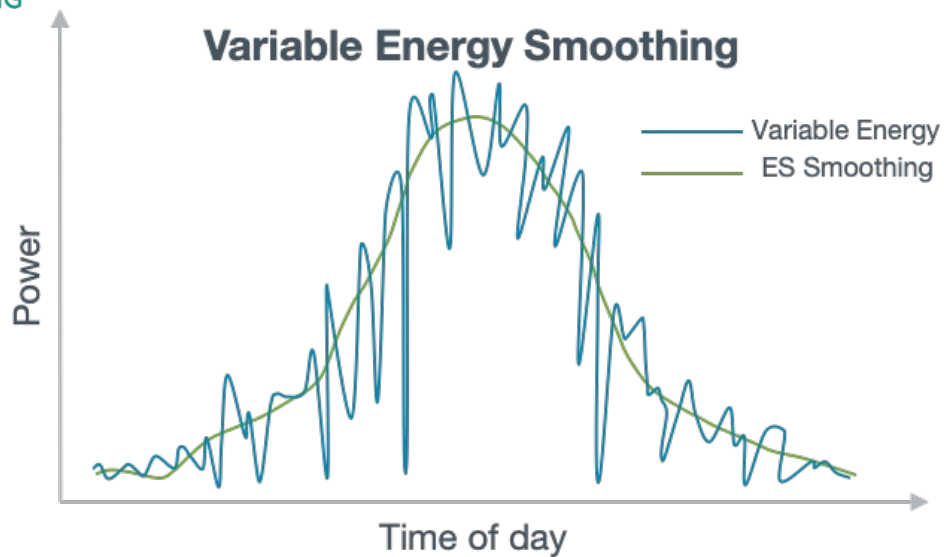


Capacity Firming allows variable energy generators to deliver consistent energy to the grid. When more energy is produced than needed, that energy is stored for when not enough energy is produced.

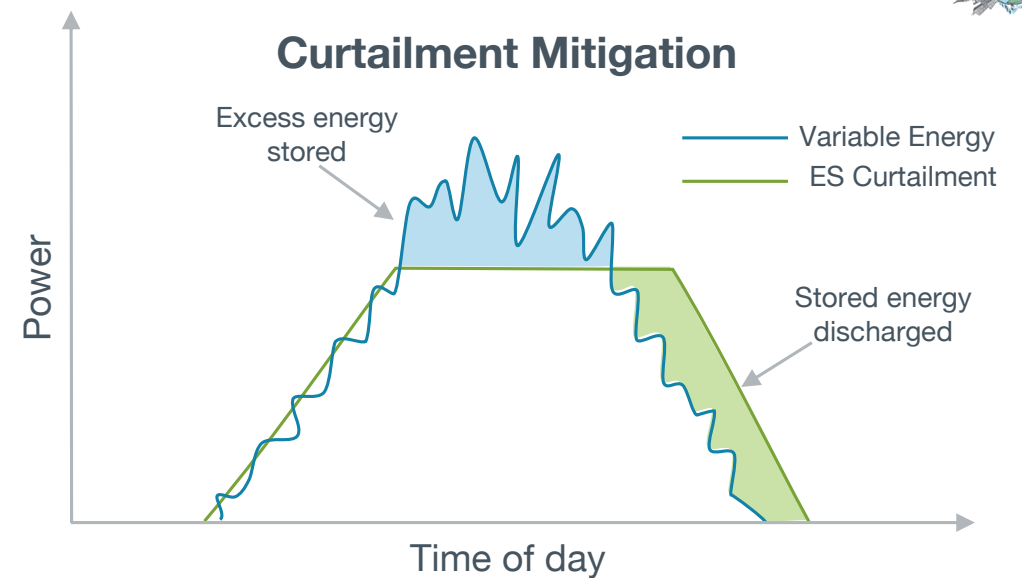
The green is excess energy stored (charged) and the blue is the energy released to the grid (discharged).



Energy storage changes the ramp rate (the slope of the graph) to allow variable energy to deliver energy to the grid at a faster rate – the steeper the slope, the faster the response time.

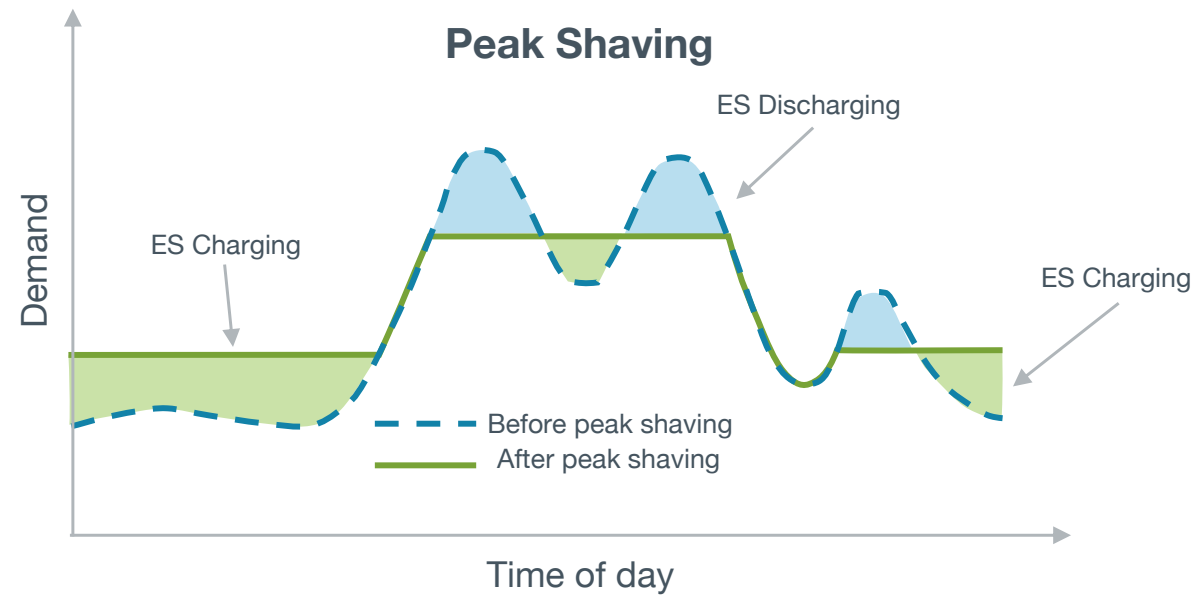


Variable energy's production fluctuates. For example, solar PV produces energy when the sun is shining, and wind energy produces energy when the wind is blowing. This results in variability in the total energy produced. Energy storage helps to smooth out the fluctuation by providing a constant supply. Energy produced from variable energy is stored into the energy storage system and is delivered to the grid from the energy storage.

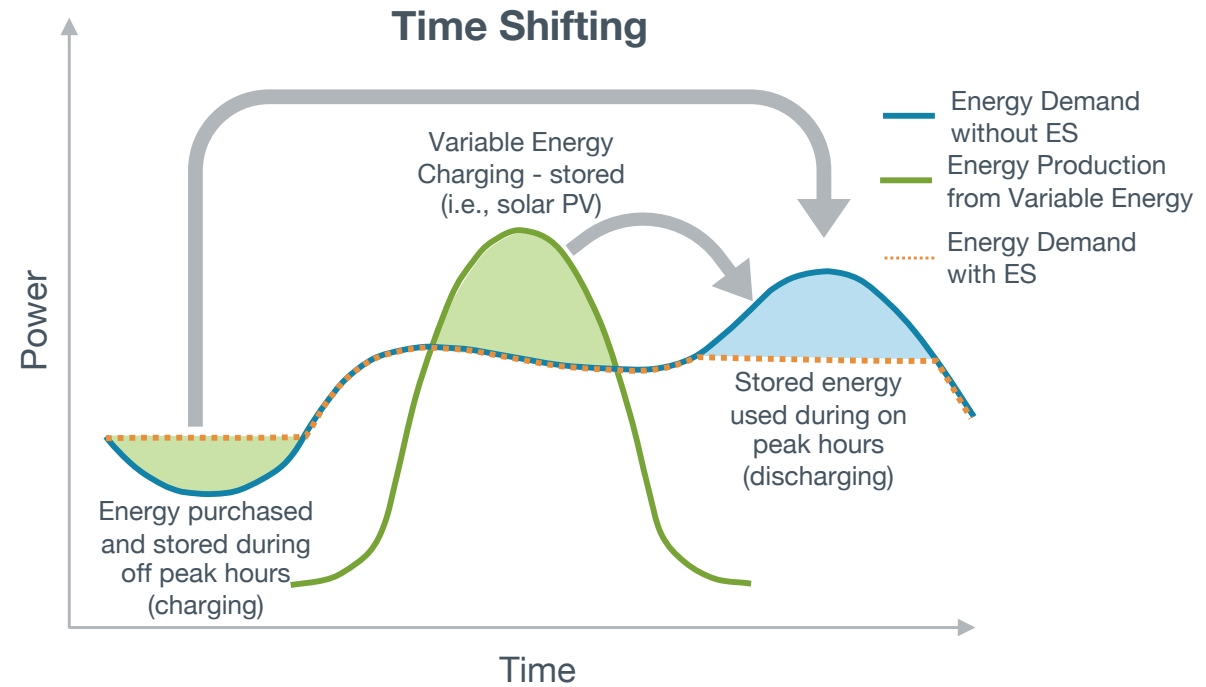


Curtailment: the action or fact of reducing or restricting something

Sometimes, there is no need for all the energy produced by a generator. Energy storage allows a generator to continue producing energy during low times. This energy is stored until required later (see right side of the graph).



Energy is stored at off peak times when the cost of energy is low. During on peak times, the stored energy is used as needed to avoid high charges. This application saves the customer money.



Similar to peak shaving, but variable energy is used on-site to generate and store energy. Energy is purchased at times of low price and stored for later use, in addition to the excess energy generated.

this is also used on the generation side

Customer Side ES Applications

Europe's Energy Storage Forecast shows high growth rates

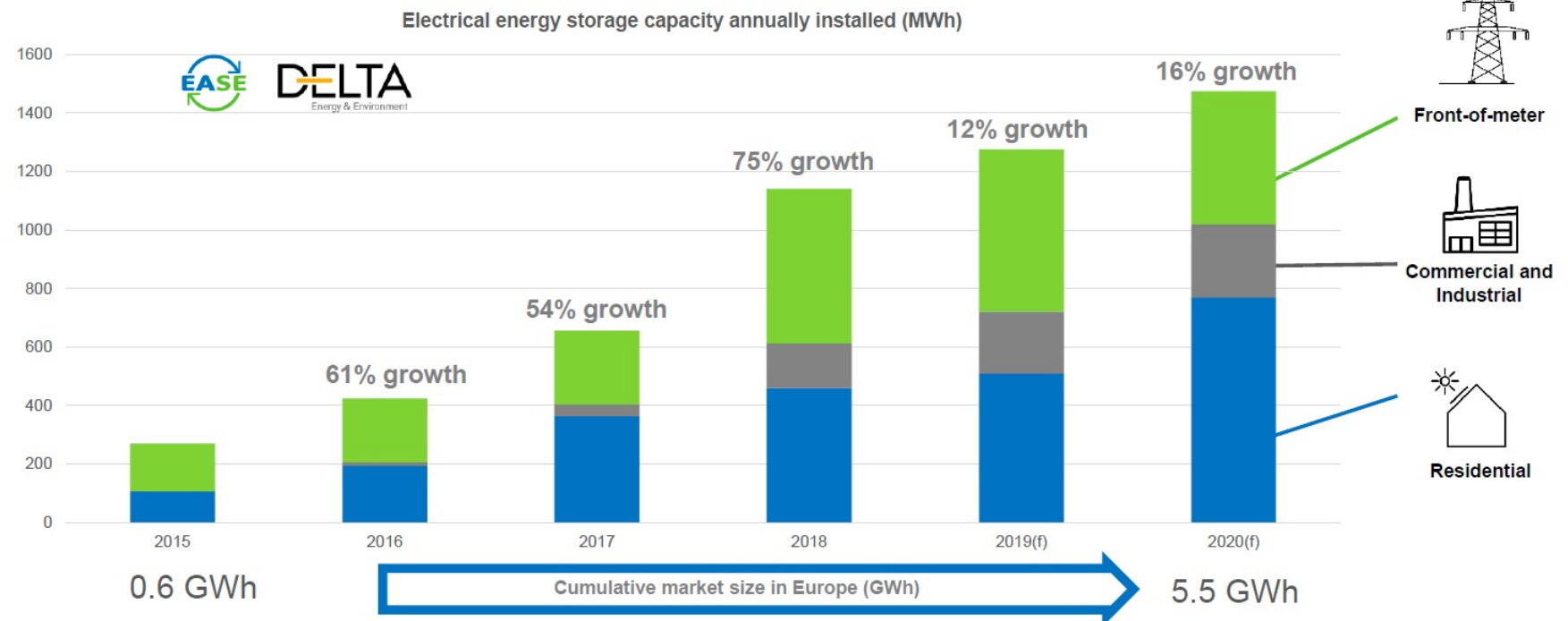
EMMES 3.0* Market figures and forecasts



Electrical Energy Storage

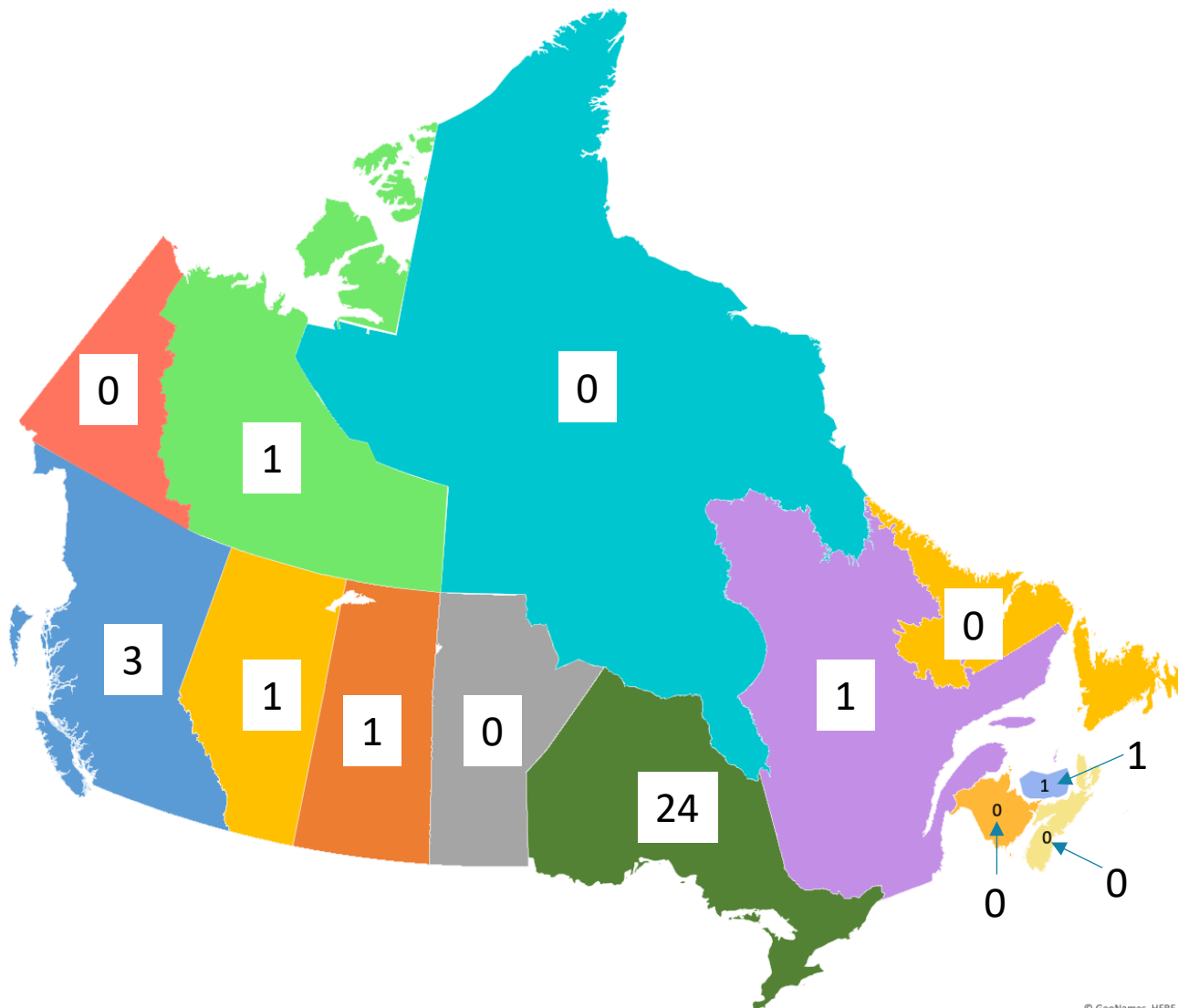
The analysis includes electrical, electrochemical and mechanical storage (with the exception of pumped hydro storage).

- High growth rate in residential, commercial/industrial and utility scale.
- The growth in 2018 was higher than expected and was the highest growth ever seen (75% increase)



Energy Storage in Canada

Number of Energy Storage Projects by Province



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Western Canada Energy Storage Projects

Province	Project	ES Technology
British Columbia	Revelstoke Hydro Battery	Pumped Hydro Storage
Alberta	Drakes Landing-Solar Thermal Heating	Thermal Storage
Saskatchewan	Cowessess First Nation High Wind and Storage Project	Lithium-ion Battery
Northwest Territories	Arctic Circle Battery Electric Storage System	Lithium-ion Battery

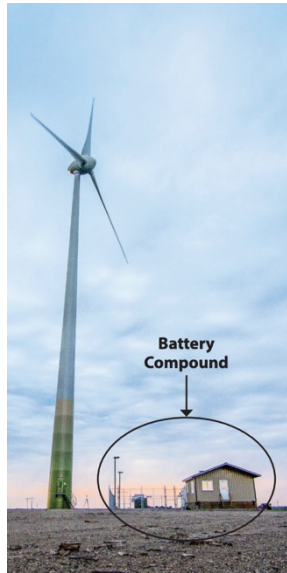
Example Energy Storage Projects



Toronto Zoo Ice Bear Ice Thermal Energy – Toronto, Ontario



Goderich A-CAES Facility – Goderich, Ontario



Cowessess First Nation Lithium-Ion Battery Storage



Drakes Landing solar Thermal Heating (Thermal Storage) – Okotoks, Alberta



Thank you!

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Foundation



Energy
Efficiency
Alberta





ACTIVITY

Technology

High Temperature
Storage

Flywheels

Low Temperature
Storage

Capacitors

Thermochemical
Energy Storage

SMES

ES Type

Thermal

Mechanical

Chemical

Electrical

Technology

Batteries

CAES

Supercapacitors

Pumped Hydro

Fuel Cells

Technology

ES Type

Technology

