Catalyzing
a Clean Future.
Every Day.

May 1, 2024

Agenda

Flow Batteries: How They Work

ESS Iron Flow Battery Function

Why ESS Iron Flow LD Batteries Are Needed

ESS Inc Introduction

ESS Inc Product Specifics and Benefits

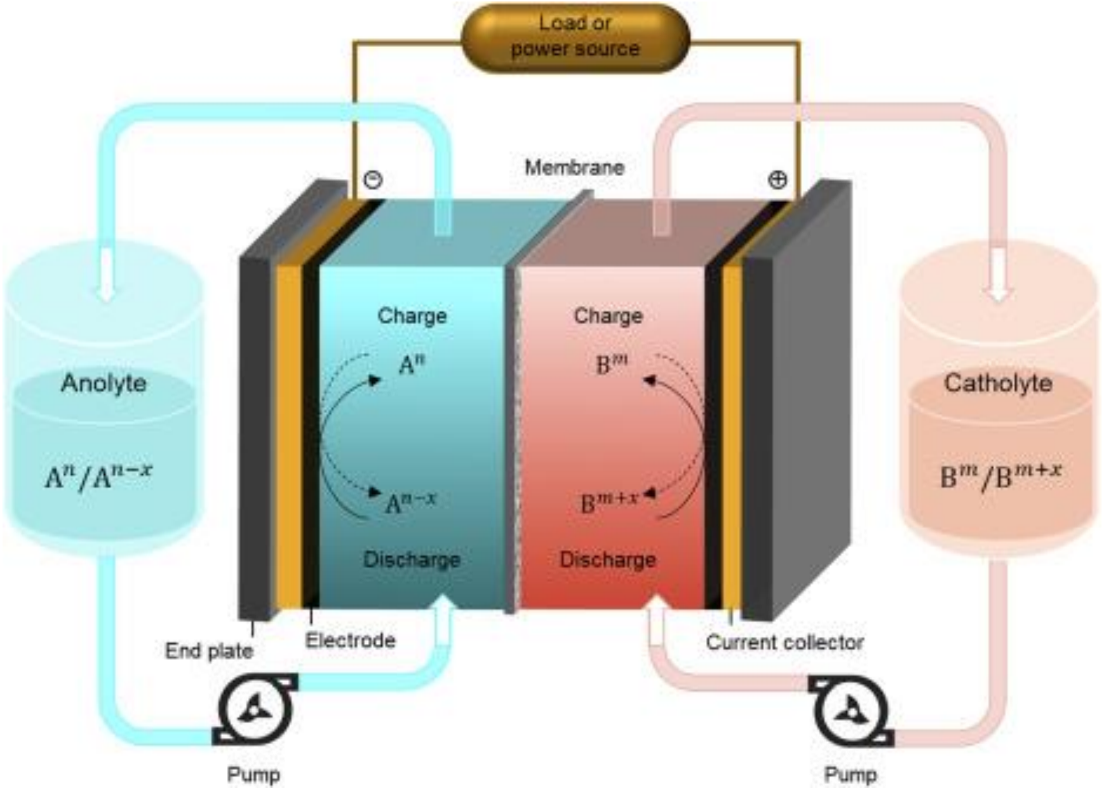
ESS Inc Product Case Studies

Q&A

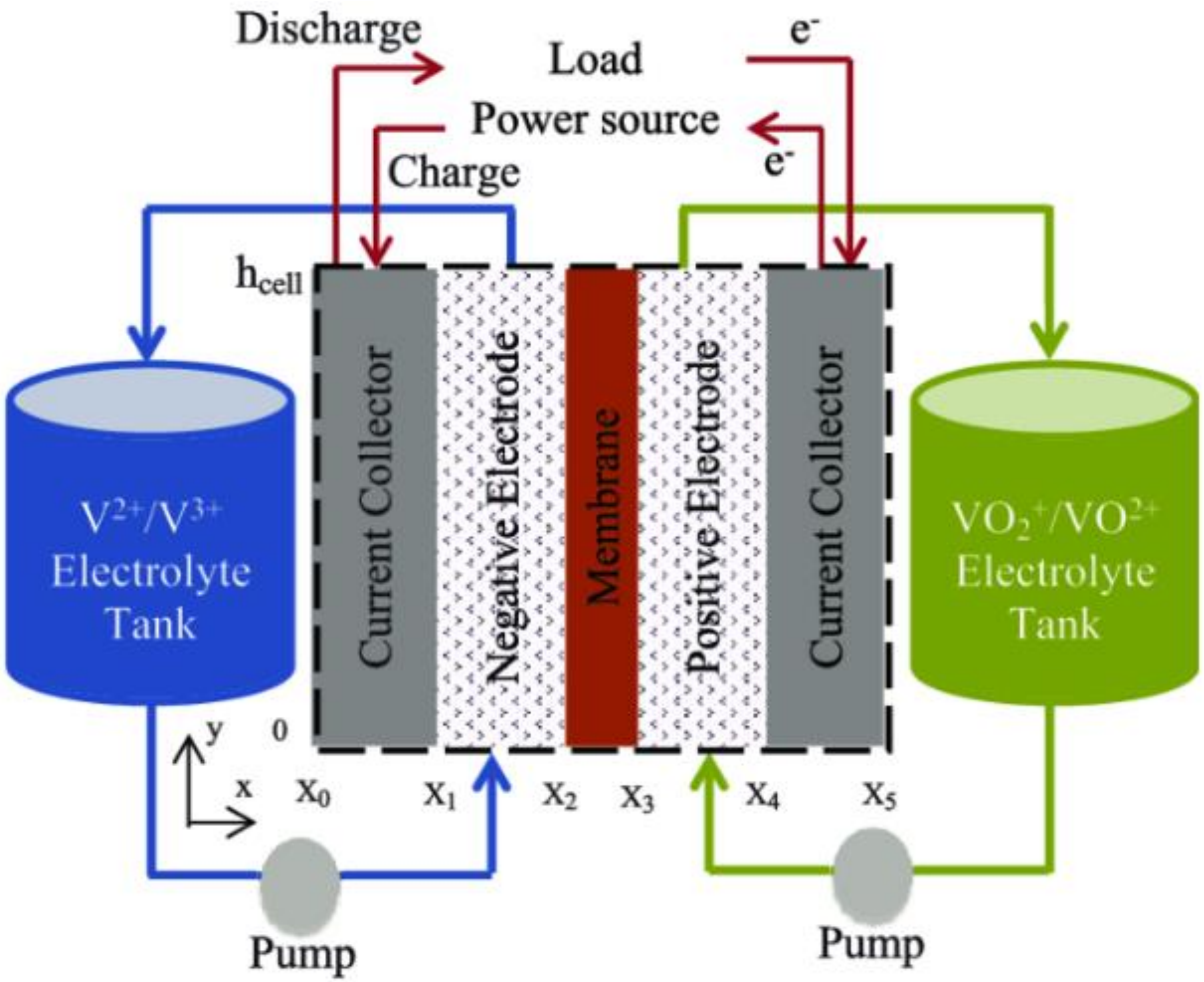
Flow Battery Basics

Redox flow batteries (RFBs) are energy storage systems that store electrical energy in chemical form. The main components of an RFB are two electrolyte solutions containing electroactive species (redox couples) that can undergo reversible reduction and oxidation reactions. The redox couples are typically stored in separate tanks and circulated through the cell stack when generating or storing electricity. There are different types of RFBs, and the terms "hybrid redox flow battery" and "true redox flow battery" refer to distinctions within this category.

1. **True Redox Flow Battery:**
   - In a true redox flow battery, both the anode and cathode electrolytes contain electroactive species that actively participate in the redox reactions. These species are responsible for storing and releasing electrical energy.
   - The electroactive species in the anode and cathode are often different, and the overall reaction involves the transfer of electrons between these species.
   - Examples of true redox flow batteries include the vanadium redox flow battery (VRFB), where vanadium ions in different oxidation states (V2+/V3+ and V4+/V5+) are used in the anode and cathode, respectively.

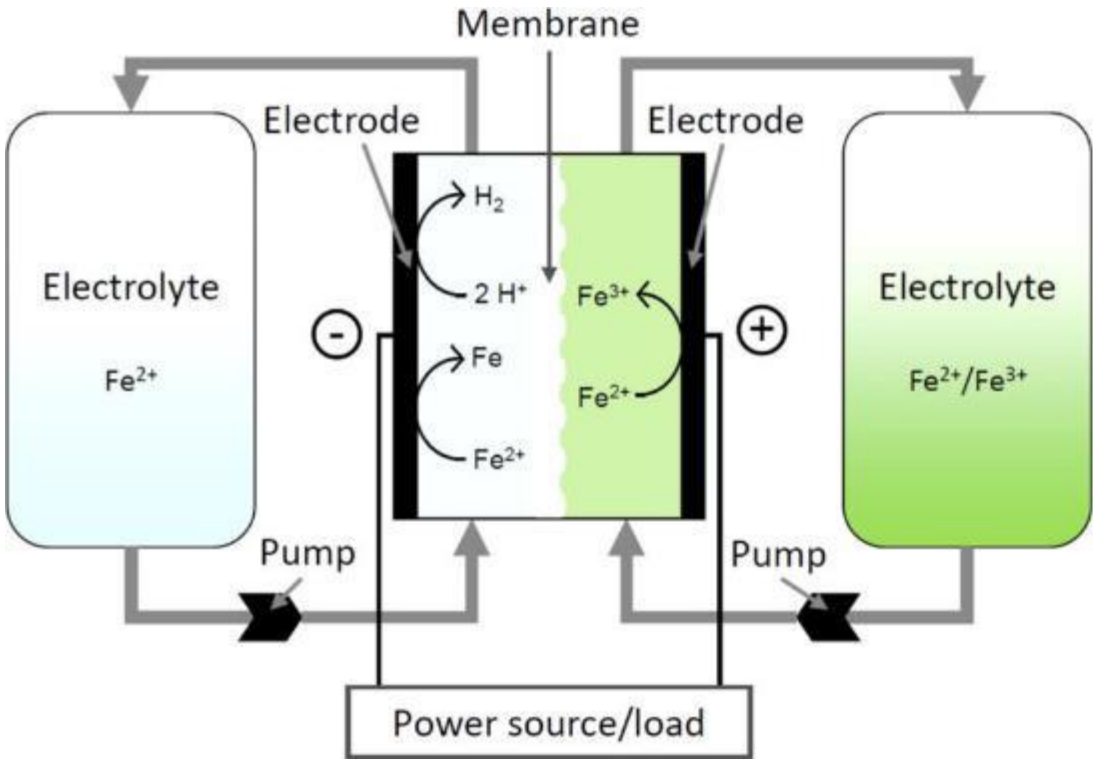


Vanadium Redox Flow Battery

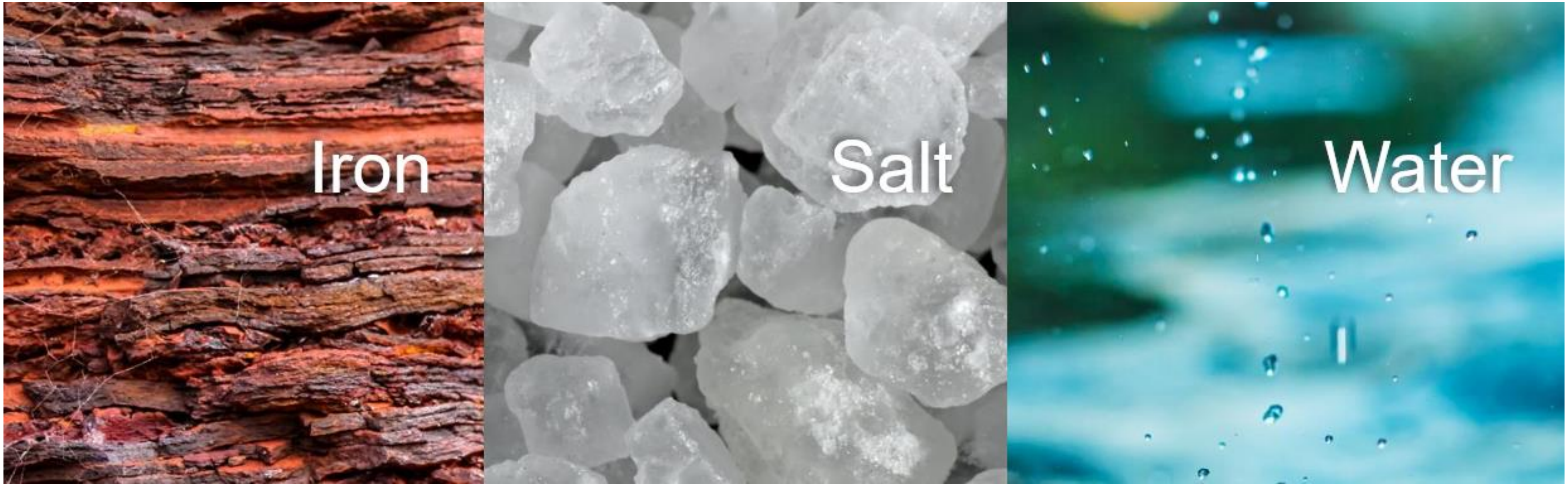


ESS Inc Iron Flow Battery

2. **Hybrid Redox Flow Battery:**
   - In a hybrid redox flow battery, one of the electrodes may undergo conventional battery reactions (e.g., intercalation or conversion reactions), while the other electrode still relies on redox reactions similar to a true redox flow battery.
   - The term "hybrid" indicates a combination of traditional battery chemistry at one electrode and redox flow battery chemistry at the other electrode.
   - This hybrid approach is designed to benefit from the strengths of both conventional batteries and redox flow batteries, aiming to improve energy density, efficiency, or other performance metrics.
   - Hybrid redox flow batteries are less common compared to true redox flow batteries.

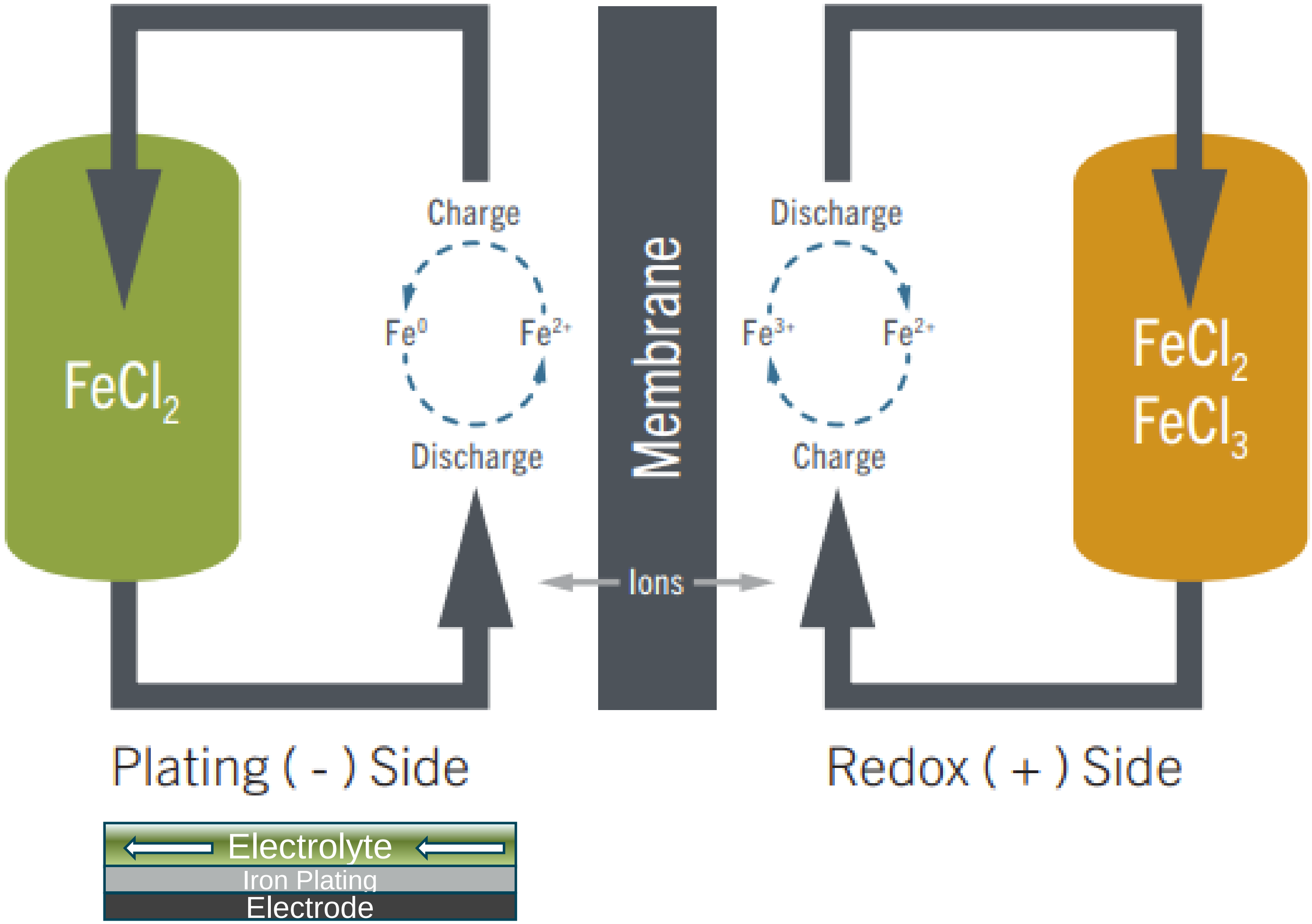


ESS Electrolyte



Plus other chemicals in minor content to act as ion carriers and catalysts

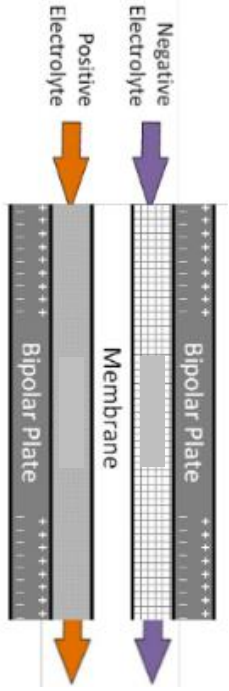
Charging/Discharging



During charging iron collects (electroplates) on the negative electrode

During discharging iron dissolves back into solution

Power Module/Stack

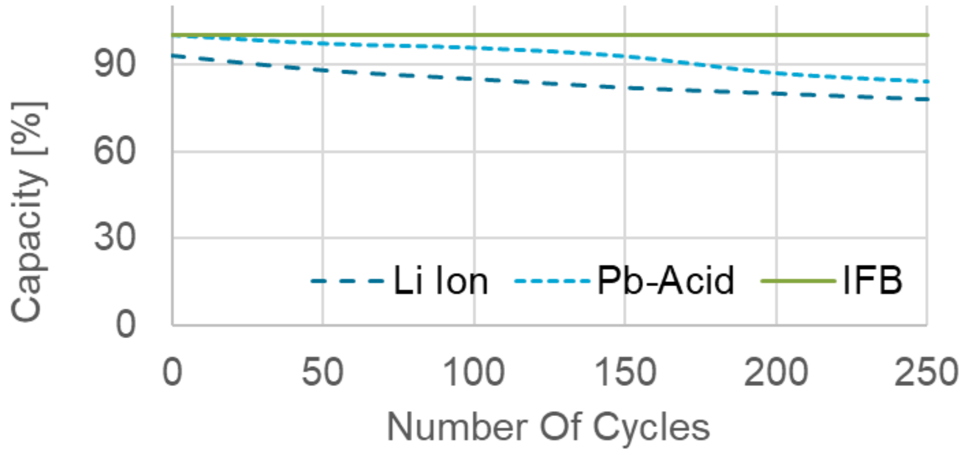


Cell

Electrolyte Health Management

- All batteries have side reactions
- Some side reactions can cause capacity loss
  - Irreversible Losses (Li+, Pb-Acid)
- The side reactions in ESS iron flow batteries are reversible
  - Reactions are reversed through electrolyte health management
  - No lifetime capacity loss!

- Two different styles of proton pump in the electrolyte health management system continuously reintegrate the hydrogen produced from the side reaction back into the electrolyte maintaining the ionic balance



Global Energy Transition + Long-Duration Storage

The Global Imperative to Transition to Renewable Energy

The world's appetite for electricity is growing unabated. Global electricity demand rose by 6% or 1,500 terawatt hours (TWh) in 2021.

The risks of today's aging energy infrastructure are readily apparent – and more dangerous. Today's solutions need to last for decades.

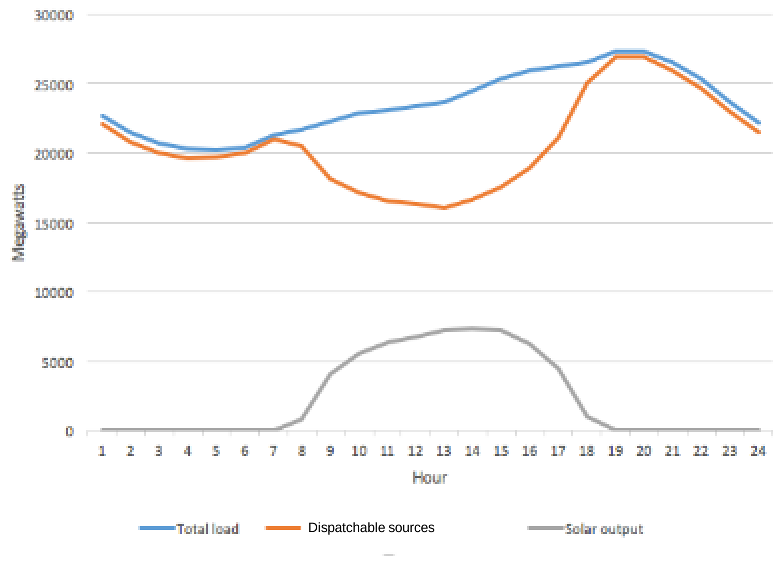
Increasing concern for energy and national security.

The cost for utility-scale solar PV power has declined 82% since 2010 and the costs for onshore and offshore wind have declined 39% and 29%, respectively
(both are now cheaper than fossil fuels).

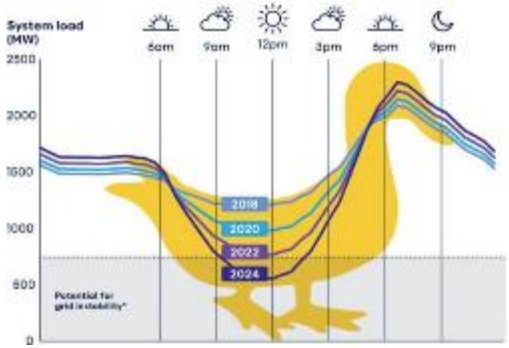
A global transition to a decarbonized world is underway.
To preserve a livable climate, greenhouse-gas emissions must be reduced to net 0 by 2050.

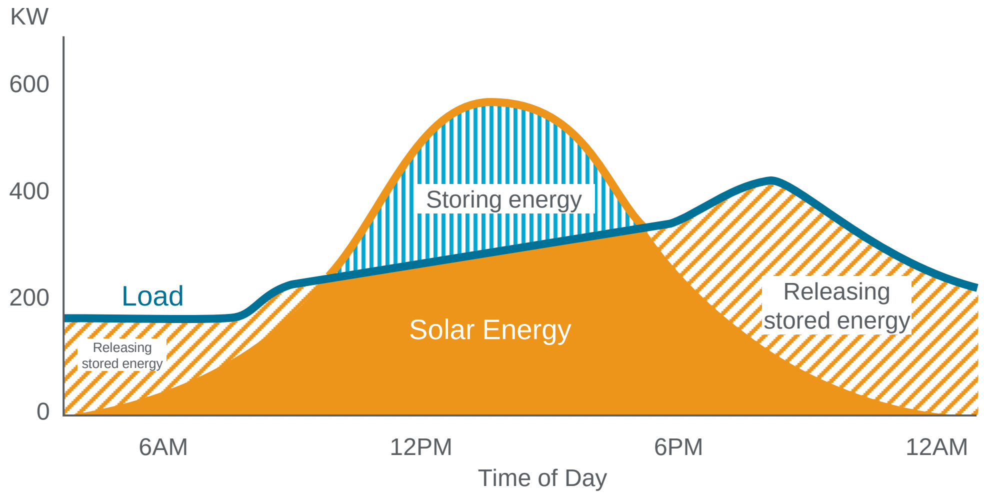
Extreme climate-driven weather events are now the norm. Deadly extreme weather events in the U.S. have cost nearly $2.5 trillion since 1980.

Renewable Penetration Drives Energy Storage Needs



The Solar Duck Curve

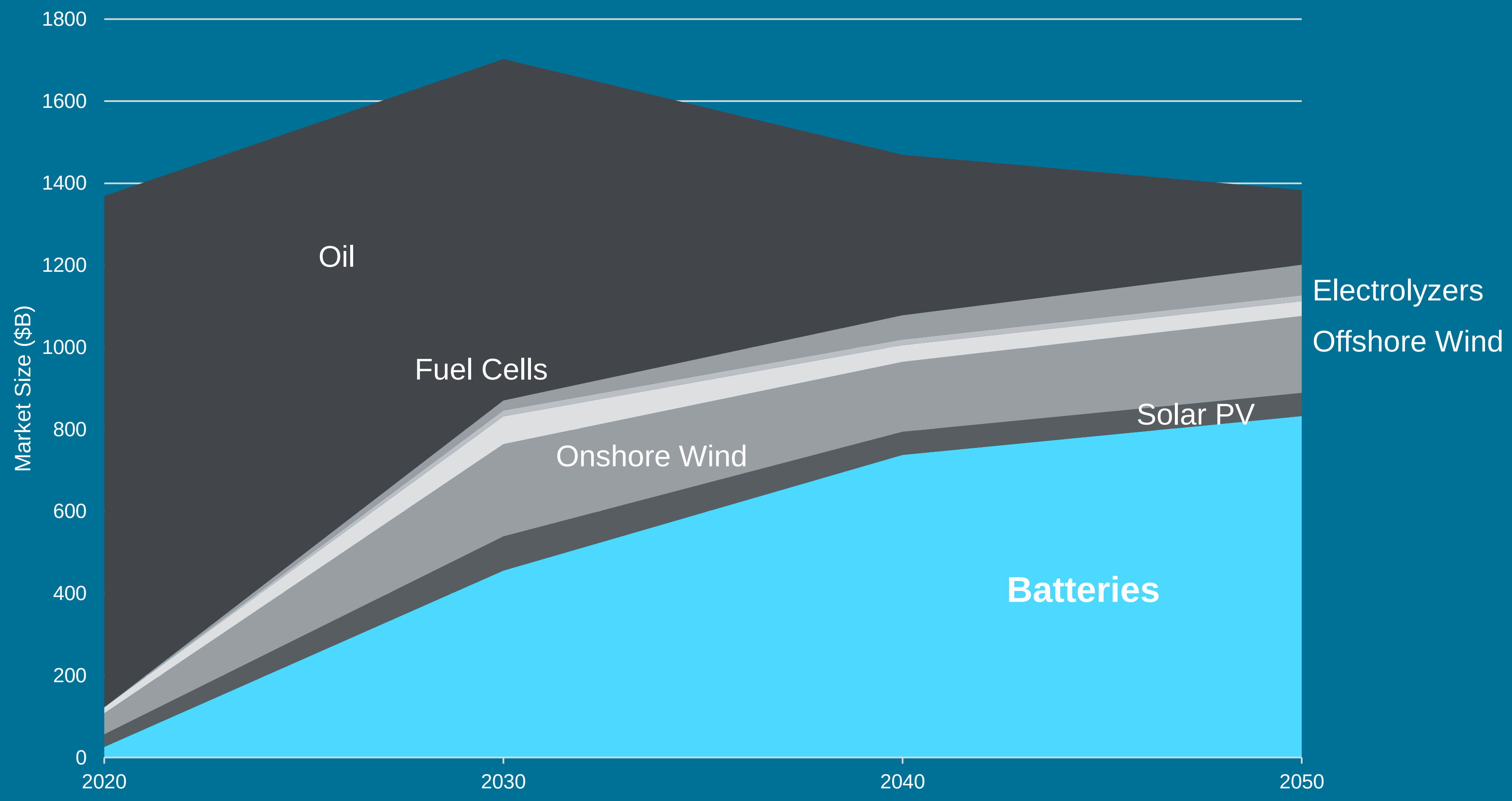




Evening use of long-duration stored energy

Lack of storage caused more than **2.6 TWh to be wasted in 2023** in California alone

Batteries are a BIG Part of the Solution



Source: IEA, World Energy Outlook, 2021

The Four Families of Long-Duration Energy Storage

10+ Hours

Electro-chemical

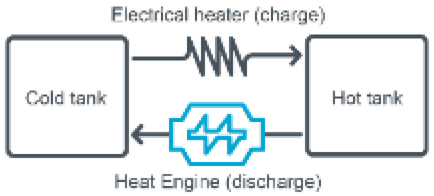
Tech examples*

Redox flow
Sodium
Metal-air

Intra-day

Multi-day

Thermal

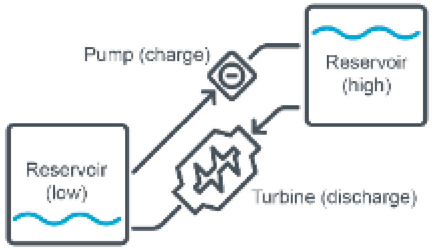


Tech examples*

Sensible heat
Latent heat
Thermo-chemical

Intra-day

Mechanical



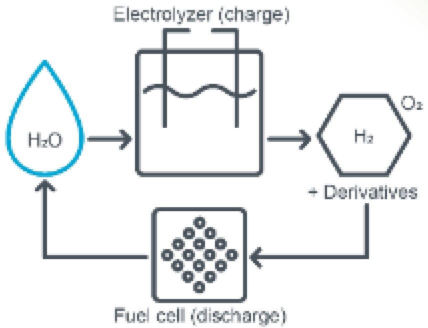
Tech examples*

Pumped hydro
Compressed air
Liquid air

Intra-day

Multi-day

Chemical



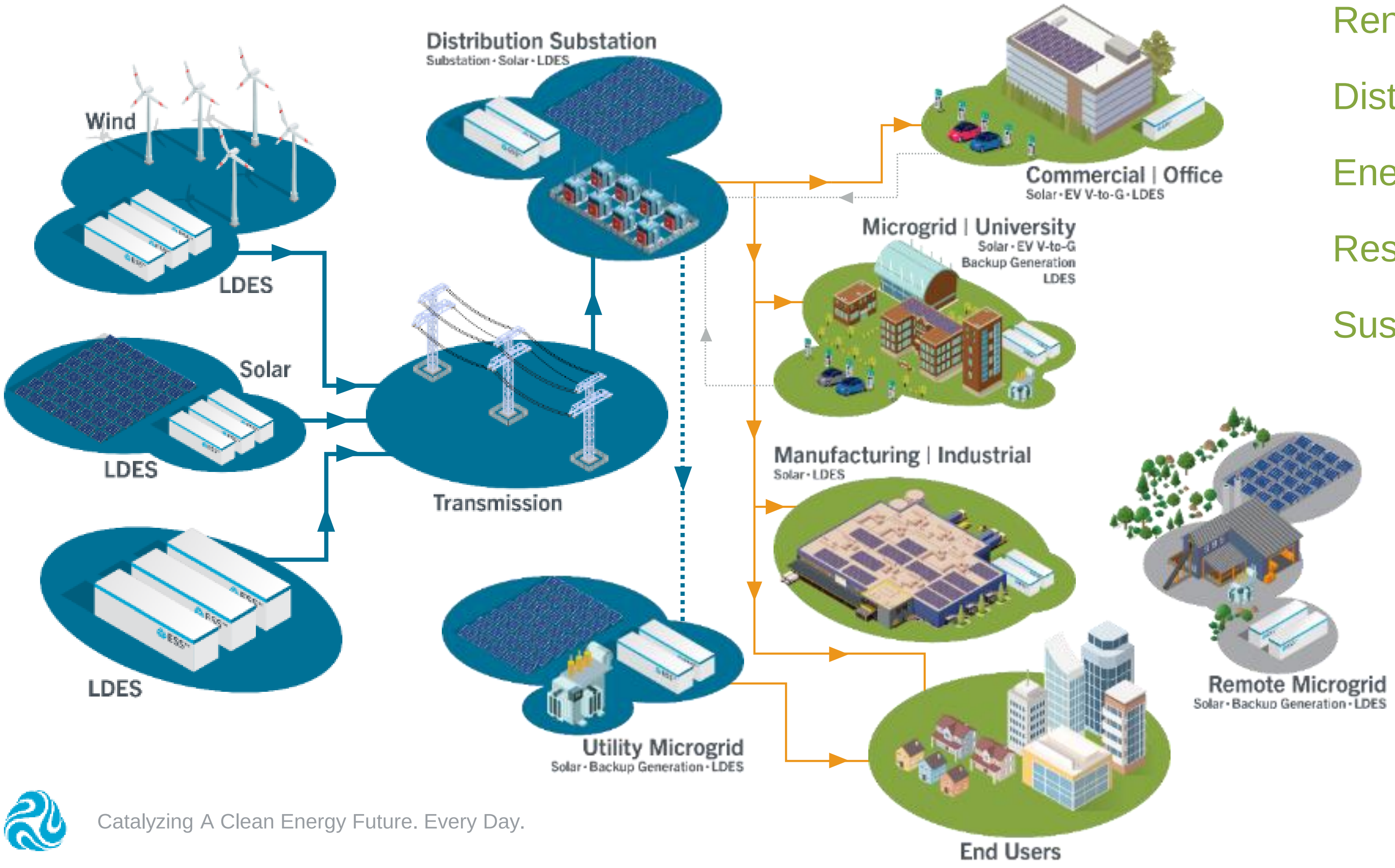
Tech examples*

Hydrogen
Ammonia
Electrofuels

Seasonal

* Non-exhaustive
Source: LDES Council / Future Cleantech Architects

How Long-Duration Energy Storage (LDES) Fits into Our Energy System



Renewable energy smoothing

Distributed energy resources

Energy cost savings

Resiliency and reliability

Sustainability goals

Two Major Value Propositions of LDES

Energy shifting

Time horizon	Role of storage		Typical solution
Intraday	Balance variable daily generation with load		8-24 hours LDES
Multiday Multiweek	Support multi-day imbalances	Absorb surplus generation to avoid grid congestion	24+ hours LDES
Seasonal duration	Support during seasonal imbalances	Mitigate extreme weather events	Pumped hydro and compressed air

Grid services

Inertia	Fast frequency response (FFR)	Primary / secondary / tertiary reserve
Reactive power / voltage control	Short circuit level improvement	System restoration / black start

ESS Inc

Company Overview

ESS	Founded in 2011 with mission to develop the safest, most cost-effective and sustainable long-duration energy storage technology
Headquarters	Wilsonville, Oregon
Facilities	250,000 ft^2 manufacturing plant Automated production line currently scaling to 2GWh annual production
Employees	300+
Technology	Iron flow battery for utility-scale and commercial applications
Publicly traded	NYSE: GWH



ESS Iron Flow Batteries

Simple but revolutionary technology purpose-built to solve energy storage, now and for decades to come

Energy Warehouse™ Overview

First commercial pilots in 2015

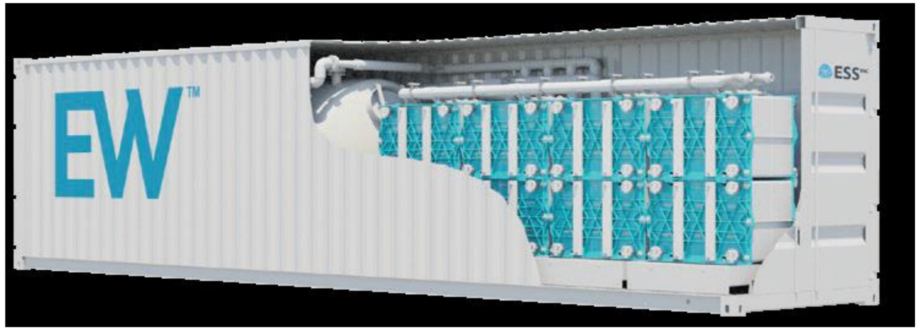
Fully integrated containerized design

Commercial shipments in 2022

Fast and easy to deploy and commission

Specifications

Features	
Rated Discharge Power	75 kW at POC
Rated Charge Power	90 kW at POC
Rated Capacity	380 kWh minimum POC
Discharge Capacity	Up to 500 kWh POC
Nominal DC Voltage	880 VDC ± 5% bi-polar
Optional AC Voltage	400 VAC / 50 Hz, 3-phase or 480 VAC / 60 Hz, 3-phase
Response Time	< 1 second depending on operation mode
Expected Life	25-year design life with no degradation
Controls	On-board battery management system: Modbus interface (SunSpec protocol)
Communication Options	24/7 remote monitoring (TCP/Ethernet interface)
Certification	Conforms to UL 1973, UL 9540, UL9540A, NFPA 855



Energy Center ™ Overview

Front-of-the-meter solution

Modular design for utility-scale applications

In production

Specifications

Features	
Configurable Range	Customizable up to GW scale
Rated Capacity	145 kW DC / 1.16 MWh DC at POC
Maximum Charge Power	174 kW
Voltage	880 VDC ± 5%
Response Time	< 1 second depending on operation mode
Expected Life	25-year design life
Module Cycle Life	>20,000 cycles
Secondary Containment	Integrated into tank container to 110% of volume of largest tank
Communication	24/7 remote monitoring (MODBUS TCP/Ethernet interface to EMS/SCADA)
Certification	Conforms to UL 1973, UL 9540 (pending), UL9540A (pending)

Benefits of
Iron Flow Batteries

ESS Benefits

What Customers Demand	ESS INC	How ESS Transforms the Grid
Long duration, no degradation	• Up to 12 hours • Unlimited cycling capability without degradation	• Can replace coal and gas with solar and wind • Designed for utility-scale applications
Low cost	• 25-year lifetime • No augmentation required	• The first truly low-cost flow battery • In commercial production today
Power on demand	• Multi-cycling, fast response capability • Operating flexibility enables multiple benefits	• Improved grid resiliency and flexibility • Enables multiple use cases
Safety, reliability, and bankability	• UL 1973, UL 9540, UL9540A, NFPA 855 • Wide operating temperature range	• Can deploy in a wide range of geographies • No HVAC needed – cuts CAPEX and OPEX
Sustainability	• Safe and sustainable • Easily sourced materials; recyclable components • “Plug and play” with 25-year design life	• Environmentally sustainable • Accelerates clean energy transition

*Certified to UL 9540 by ETL

Sustainability Advantages of Iron Flow Batteries

Responsibly sourced materials

- Earth-abundant iron, salt and water

Global warming potential (GWP)

- 67% lower CO_2 emissions than Li-Ion[1]

Recyclability

- Contains all natural and easily sourced materials
- Recyclable components

Note — GHG impact is dependent on specific Li-Ion chemistry.

1 — He, H. et al. "Flow Battery Production: Materials Selection and Environmental Impact." Journal of Cleaner Production. Vol. 269. 1 October 2020.
Noguera, E., Comparative LCA of stand-alone power systems applied to remote cell towers, 2014.

ESS Use Cases

Representative ESS Deployments


Distributed Generation


Utility-Scale DER

Airside Operations

Utility-Scale DER

Green Baseload Energy

ESS Technology Serves a Wide Range of Use Cases

Green Baseload Energy

Use case
- Replaces coal or fossil baseload generation with renewables
- Scalable support for critical infrastructure

Project benefits
- Enables retirement of fossil/coal power stations and deep grid decarbonization
- Eliminates CO_2
- Creates and supports local employment

Airside Operations

Use case
- Electrification of airside ground operations
- EW will store energy for a fleet of E-GPU’s, replacing planeside diesel generators

Project benefits
- Safely supports passenger aircraft ground operations
- Reduced carbon emissions and improved ground-level air quality
- Supports Schiphol Group’s ambitious 2030 carbon goals

Utility-Scale DER

Use case
- Standalone LDES storage for large-scale renewable integration
- DER for community resiliency and environmental justice

Project benefits
- Equipment supply surety that aligns with strategic infrastructure needs
- Local economic development
- Enables deep decarbonization

Distributed Generation

Use case
- Behind the meter microgrid
- Energy shifting, load management
- Resiliency

Project benefits
- < 5 yr. payback on energy cost savings
- >$800K in resiliency benefits

Thank You!

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