IRON FLOW BATTERIES:
Clean, Safe, and Sustainable Energy Storage

ESS INC
CATALYZING A CLEANER FUTURE

IRON FLOW BATTERIES COMPARED TO OTHER BATTERIES

- Minimal resource depletion
- Lower energy consumption in production
- Fewer greenhouse gas emissions
- Less air and water pollution
- More ozone support

The most sustainable battery chemistry to produce

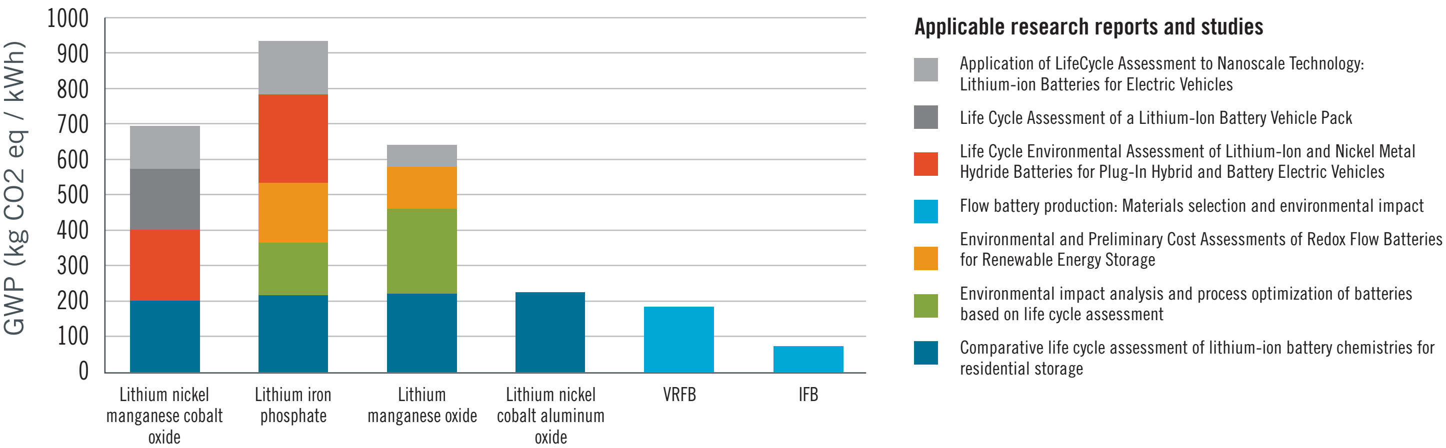
Life Cycle Analysis (LCA Comparison)

Long-duration energy storage systems are crucial for leveraging and managing intermittent solar and wind power. But, is the storage solution you're considering as clean as it can be? It is if you're looking at iron flow batteries.

In an independent assessment conducted at the University of California-Irvine, scientists evaluated the cradle-to-gate environmental impact of three different flow battery types[1]. Researchers assessed what happens before the in-use and end-of-life phases of a product's life cycle and provided insight into the environmental impact associated with the production of the iron flow battery and made comparisons between the impact of the lithium-ion and other flow battery types.

Iron flow batteries proved to be the cleanest technology with the lowest global warming potential (GWP) compared to batteries using vanadium and zinc. They're also significantly less harmful to the environment than lithium-ion batteries.

Not All Energy Storage Solutions Are Created Equal



The graph above displays the Global Warming Potential (GWP) measurements of varying batteries. As noted, ESS Inc.'s all-iron technology proved to be the cleanest compared to batteries using vanadium and zinc.

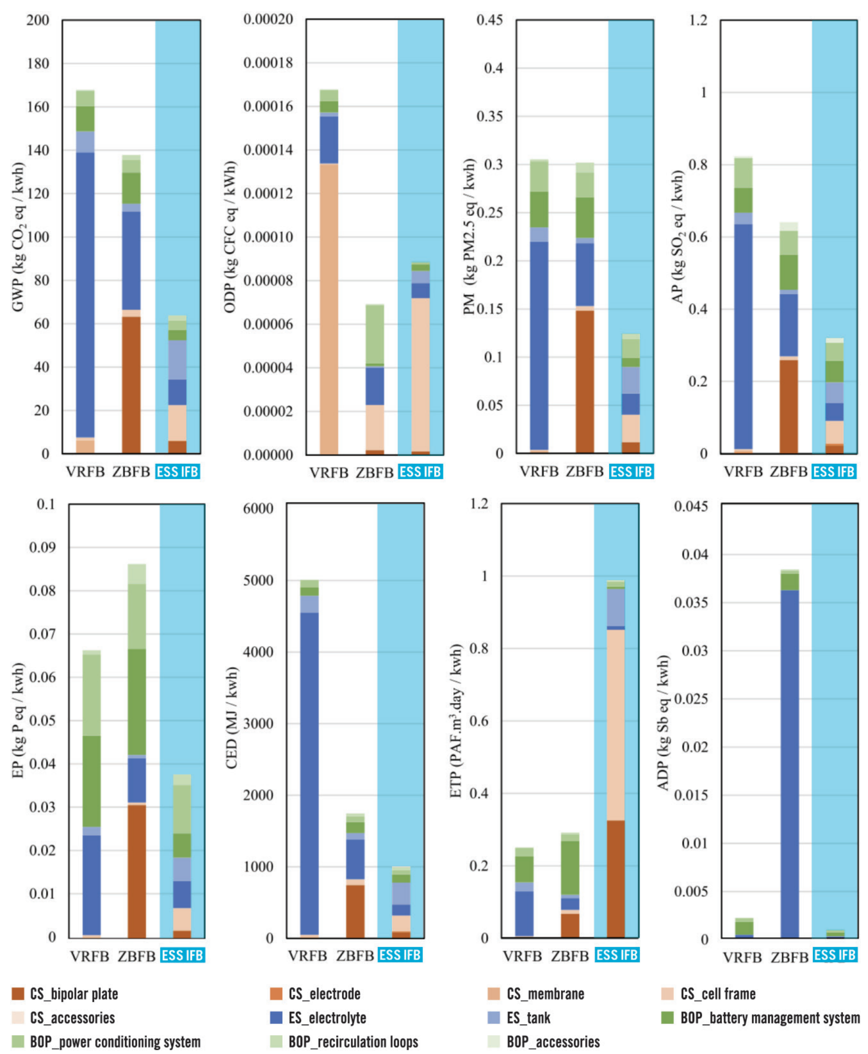
1. Haoyang, He et. Al. Flow Battery Production: Materials selection and environmental impact. Journal of Cleaner Production, v. 269, 1 October 2020. https://www.sciencedirect.com/science/article/abs/pii/S095965262031787X?via%3Dihub

PRODUCTION MATTERS

What happens before the use and disposal of a device like an energy storage battery? Raw materials acquisition, processing of those materials to get them into usable form, manufacturing of individual product components and production of the battery itself. These steps often involve resource mining, which may lead to resource depletion, fossil-fuel-based energy consumption and more.

All of these activities can impact the natural world. In the UC-Irvine study, researchers examined factors related to ecological risk that could result from raw materials extraction, processing and product production of flow batteries using different chemistries. Here is a list of those factors and why they're important.

Environmental Impact Assuming the Harmonized System Boundary



Flow battery types include: VRFB = vandadium redox flow battery; ZBFB = zinc bromine flow battery; and IFB = all-iron flow battery. Flow battery components include: cell stack (CS) , electrolyte storage (ES) and; balance of plant (BOP).

SUSTAINABLE
100% RECYCLABLE

GLOBAL WARMING POTENTIAL (GWP)

Global warming potential calculates emissions of greenhouse gases multiplied by their respective potency. For instance, methane is considered to be about 85 times more potent and harmful than carbon dioxide.

OZONE DEPLETION POTENTIAL (ODP)

The ozone depletion potential (ODP) of a chemical compound is the amount of degradation to the ozone layer it can cause.

ACIDIFICATION POTENTIAL (AP)

Acidification increases the pH of soils and water bodies. As evaporation occurs, the moisture can precipitate back down as acid rain, harming both plants and animals. Acidity is especially harmful to marine animals that require calcium carbonate minerals to grow shells because it makes ocean water corrosive and shells dissolve.

FRESHWATER EUTROPHICATION POTENTIAL (EP)

Freshwater eutrophication occurs when nutrients discharged in waterways or soil lead to excessive growth of aquatic plants or algal blooms, which can be toxic. Eutrophication disrupts aquatic food chains and may prevent oxygen from getting into the water, creating a dead zone where no organisms can live.

ABIOTIC RESOURCE DEPLETION POTENTIAL (ADP)

Abiotic resources are natural resources that are non-living, such as crude oil, lithium or iron. Once a resource becomes depleted and rarer, it also becomes harder to extract. This can lead to more cost—both financial and ecological—in the extraction process.

CUMULATIVE ENERGY DEMAND (CED)

How much fossil-based energy goes into mining operations and activities that produce something? This factor measures it.

FINE PARTICULATE MATTER

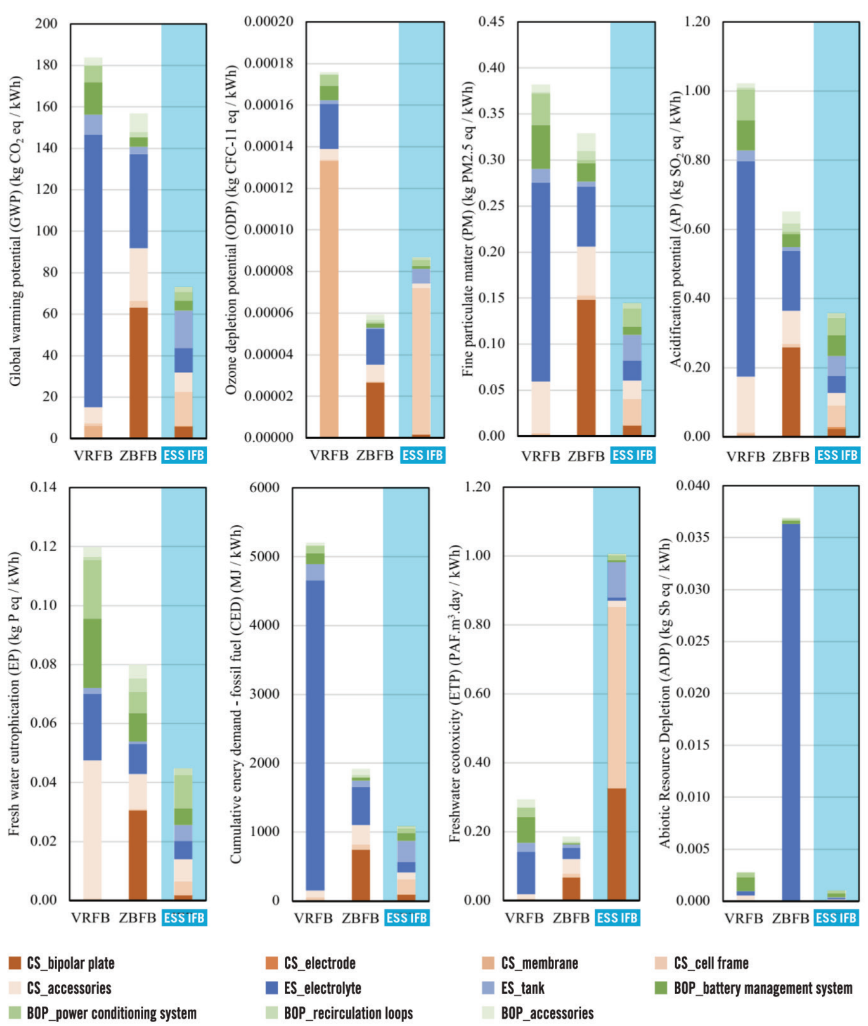
Fine particulate matter can be inhaled, causing health issues for people and animals. It also is the main reason for reduced visibility—haze—in the U.S.

Compared to zinc- and vanadium-based flow batteries, iron flow batteries are the cleanest in six of the seven environmental impact factors noted above.

LI-ION BATTERIES: NO COMPARISON

While UC-Irvine's research excludes lithium-ion batteries in the study, there are known differences in the environmental impact of Li-ion and iron flow battery production.

Potential Environmental Impact of Flow Battery Production by Battery Component



Flow battery types include: VRFB ¼ vanadium redox flow battery; ZBFB ¼ zinc-bromine flow battery; and IFB ¼ all-iron flow battery. Flow battery components include: cell stack (CS), electrolyte storage (ES) and balance of plant (BOP).

ECO-FRIENDLY

NON-TOXIC • EASILY RECYCLABLE

MORE MINING

Compared to earth-abundant iron, the amount of lithium on our planet is miniscule. The less abundant a mineral is, the more land you must mine to find it. That creates more scars on the land and ecosystem disruption. Rare minerals also usually require more processing, which results in more cost, energy use and potential pollution.

MORE INFRASTRUCTURE

More than half the world's lithium supply lies in the brine under the desert salt flats of Bolivia, Chile and Argentina. Extracting this lithium involves pumping some 500,000 gallons of water per tonne of lithium into the land to bring the brine to the surface. Because the South American "Lithium Triangle" region is so dry, water may need to be transported to the mine. That can add miles of pipeline to the environmental degradation lithium mines already create.

MORE WATER POLLUTION

Toxic chemicals have leached out of lithium mining operations around the globe, polluting soil and waterways, harming plant and animal life in mining areas.

IRON FLOW BATTERIES: AN ECO-FRIENDLY ENDING

The life cycle of a product also includes its disposal. Compared to lithium-ion batteries, iron flow batteries offer the most environmentally friendly disposal options.

Li-ion batteries:

- Require costly, energy-intensive smelting operations for recycling
- Contain a wide variety of materials, which makes recycling more difficult
- Are difficult to dismantle for recycling
- Are classified as hazardous waste due to combustibility and chemistry involved

Iron flow batteries:

- Contain no toxic materials
- Require no special permits for disposal
- Can easily be broken down into components and recycled

SUMMARY

There's little difference in the environmental impact of one battery to another when batteries are in use. What differentiates iron flow batteries from other types is the environmental impact of production and end-of-life activities. Iron flow batteries are cleaner to produce and easier to recycle and reuse electrolyte at end of life.

Along with a greener life cycle, iron flow batteries have longer life: 20 years, versus the 7-to-10-year life of a heavily cycled Li-ion battery.

There's less environmental impact when you need to build fewer batteries over the long run. That, too, makes iron flow batteries the eco-friendly choice.

ABOUT ESS INC.

Established in 2011, ESS Inc. manufactures low-cost, long-duration iron flow batteries for commercial and utility-scale energy storage applications requiring 4-10+ hours of flexible energy capacity. The Energy Warehouse™ (EW) and Energy Center™ (EC), use iron, salt, and water for the electrolyte, and deliver an environmentally safe, long-life energy storage solution for the world's renewable energy infrastructure. With its safe, earth-abundant, proven iron flow battery technology, ESS Inc. is helping project developers, utilities, and EPC's make the transition to more flexible non-lithium-ion storage that is better suited for the grid and the environment. www.essinc.com

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