Flow Batteries: A Solution to the Energy Storage Problem

Prepared By:

Akshat Reddy Gavva, 219299288
Joshua Mohammed-Ali 219614502
Avery Backus 219767888
Kia-Mfumu Sita, 219636067
Evan John Hernan Rocamora, 219533140

Date of Presentation: April 10, 2024

Introduction

- “With the sort of changes we are seeing in energy systems around the world, cheaper and better storage is going to be a big part of the solution”
    - Jim Watson, Director of the UK Energy Research Centre
- Generating clean energy is challenging
    - The power needs of a city often peak when solar and wind power outputs are at their lowest.
    - A grid-scale energy storage system must be implemented to effectively use renewable energy as the main source of energy across the world.
    - The most prominent system uses a technology called hydro pump storage but is geographically limited
- PHES systems make up about 96% of the world’s energy storage, but are slowly being replaced by other sources as VRE sources become more prevalent.

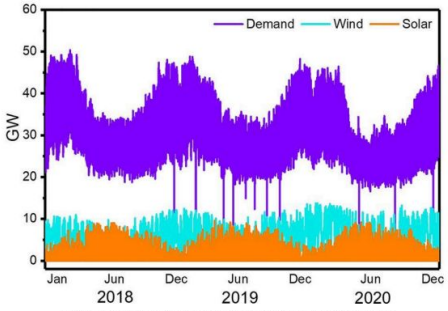


FIG.1, Wind & Solar output compared to energy demand over 1 year

The Problem

This report addresses the energy storage problem highlighted by Jim Watson, Director of the UK Energy Research Centre, as part of the challenges identified in BBC's list of 50 significant challenges for the 21st century.

- Renewable energy, such as solar and wind power, is intermittent, leading to unstable power supply during peak demand.
- Effective energy storage solutions are required to store excess renewable energy for later use when demand is high.
- Traditional storage methods like hydro pump storage have geographical limitations, hindering widespread implementation.
- Developing versatile and efficient energy storage systems to ensure reliable power supply from renewable sources.

What are Flow Batteries

- Consists of positively and negatively charged tanks of electrolyte
- Tanks are separated by membrane allowing electron transfer
- Solutions can be made of vanadium, iron, bromine etc.
- Vanadium is most commonly used today
- Modular systems allow for flexibility to accommodate various energy storage needs

Mechanics of Flow Batteries

- Rely on Redox reactions
- Battery discharges and charges are done through the transfer of electrons between electrolyte tanks
- Due to vanadium’s many oxidation states, it can be used for the catholyte and anolyte
- Pumps are used to circulate the fluids

Evan John Hernan Rocamora

Advantages and Disadvantages of Flow Battery Storage

Advantages:

- Flexibility and Modular nature
- Flexible design allowing for certain modifications including capacity and power without requiring changes to the entire system
- Scalable, as the battery is only limited in energy capacity by the size of the tank, which is better compared to Pumped Hydro Energy Storage systems with fixed reservoir volumes
- Moderate lifespan that operates for up to 14000 cycles with efficiencies up to 85% [1]

Disadvantages:

- Energy density is lower than similar sized batteries, ex. Lithium-Ion Batteries [1]
- Larger in size that takes up more room with less energy stored
- Less space efficient

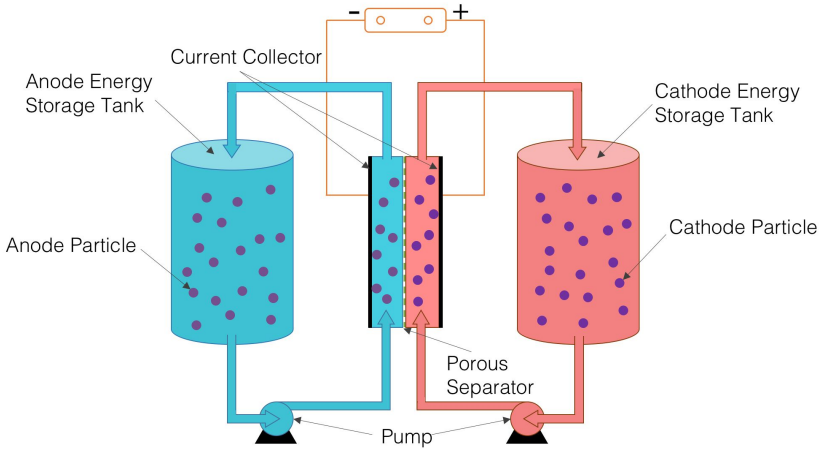
Flow Battery Variants

Innovations in this technology has lead to new types of flow batteries aiming to prolong lifespan, increase energy density, and lower costs.

- Iron-based Aqueous Redox Flow Battery (IBA-RFB):
  - Aims to replace vanadium-based solutions.
  - Utilizes cheaper electrolytes like iron-chromium, iron-lead, etc.
  - Operates at lower temperatures, enhancing safety.
  - Offers higher energy density than VRFBs.
- Zinc-Bromine Redox Flow Battery (ZRFB):
  - Boasts virtually unlimited lifespan.
  - Allows 100% Depth of Discharge (DoD).
  - Requires special agents to prevent bromide emissions, increasing cost.

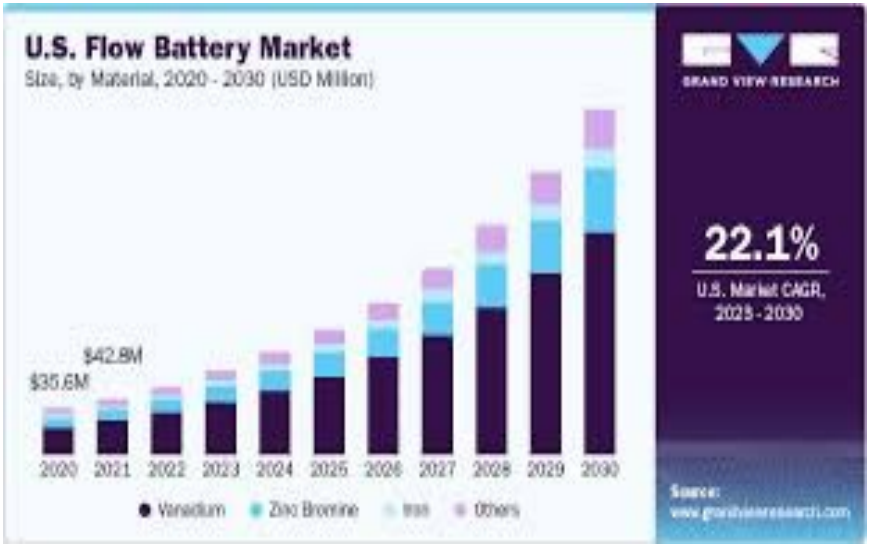
Flow Batteries vs. Lithium Ion Batteries

- Flow batteries are rising as a cost-effective alternative to lithium-ion (LIB) batteries in the energy storage industry.
- While lithium-ion dominates portable and automotive markets, flow batteries excel in large-scale storage, offering lower maintenance costs and enhanced operational safety.
- Flow batteries have a lower energy density than LIBs, limiting their use in compact devices.
- However, their safety features, including lower operating temperatures, and potential cost savings in large installations make them ideal for grid-scale energy storage solutions.



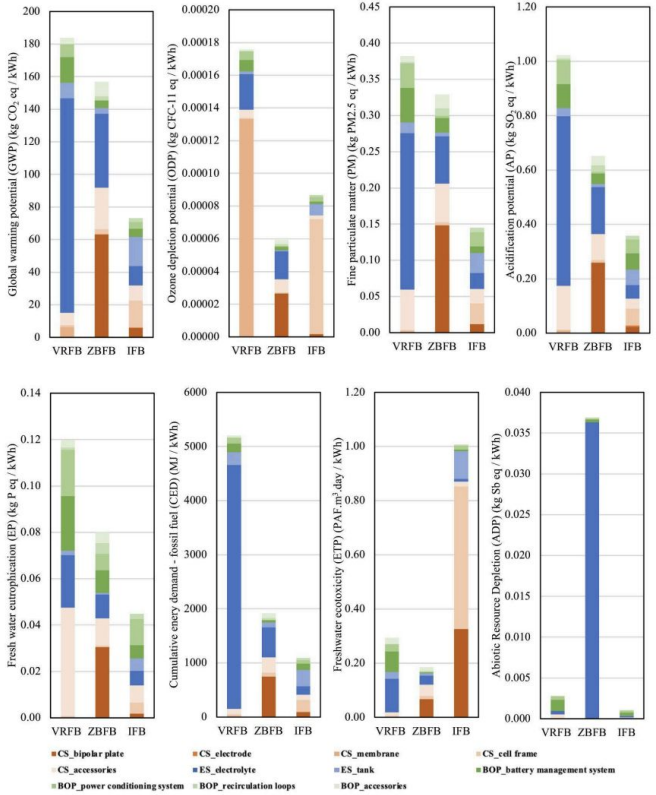
Current Industrial Applications of Flow Batteries

- Flow batteries are increasingly popular for large-scale energy storage.
- Unienergy Technologies' installations highlight their substantial storage and delivery capabilities.
- Projects in China and Japan (e.g., Minami Hayakita substation, Rongke Power storage facility) demonstrate scalability and potential.
- These examples underline the practicality and efficiency of flow batteries in real-world scenarios.
- Growing confidence in flow battery technology to meet modern energy storage demands.



Environmental Impact of Flow Batteries

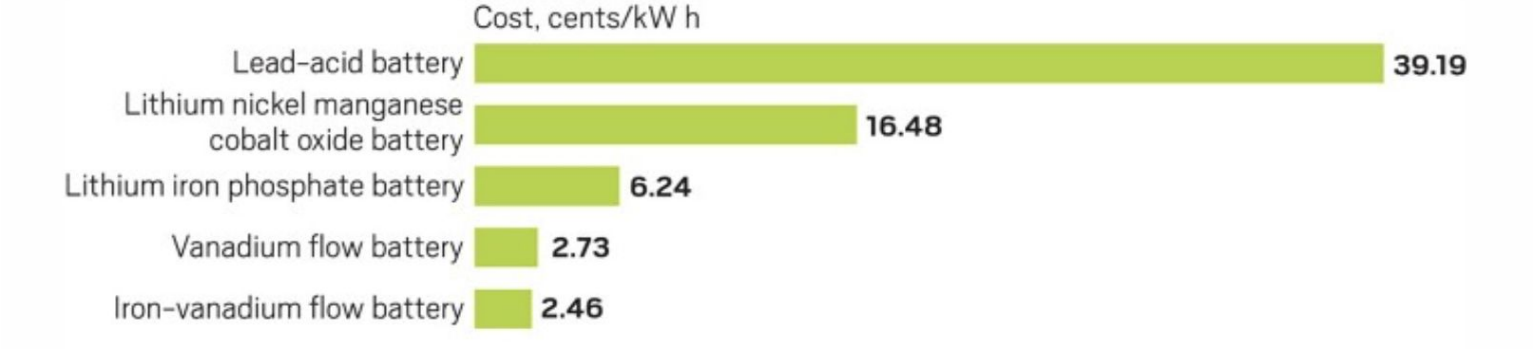
- Flow batteries are a sustainable energy storage solution, reducing reliance on non-renewable sources.
- Design variations among flow batteries affect their environmental footprint.
- Some types of flow batteries have a significantly lower environmental impact.
- VRFBs (Vanadium Redox Flow Batteries) impact the environment mainly through their electrolyte composition.
- Innovations in technology and material selection are key to minimizing environmental impacts.
- These efforts aim to make flow batteries an environmentally friendly option for future energy storage needs.



Financial Viability of Flow Batteries

The economic aspect of flow batteries becomes increasingly favorable as they scale up, despite their low energy density. This characteristic makes them less suitable for compact devices but highly effective for large-scale energy storage, where their cost-efficiency shines.

Flow batteries exhibit a unique cost structure, where their lifetime costs decrease with larger installations, especially for applications with discharge times between 10 and 36 hours. This makes them an attractive option for wind turbine energy storage and other large-scale renewable energy applications, highlighting their financial viability in the energy sector.



References

[1] Eduardo Sánchez-Díez, Edgar Ventosa, Massimo Guarnieri, Andrea Trovò, Cristina Flox, Rebeca Marcilla, Francesca Soavi, Petr Mazur, Estibaliz Aranzabe, Raquel Ferret, “Redox flow batteries: Status and perspective towards sustainable stationary energy storage” 1 January 2021 available:https://www.sciencedirect.com/science/article/pii/S0378775320311083 [Accessed 2024/03/04]

[2] Huan Zhang, Chuanyu Sun “Cost-effective iron-based aqueous redox flow batteries for large-scale energy storage application: A review” 1 may 2021 available:https://www.sciencedirect.com/science/article/pii/S0378775320317286?casa_token=0VIaApXbgQ8AAAAA:tTtAx9_6D24olMlxjIueBeVTQrXiH3FeosPnSO mHtejB2YHp6Y6-j8NcPwYkhm2MLfQHwJ1r [Accessed 2024/03/04]

[3] Guodong Li, Wei Chen, Hao Zhang, Yongji Gong, Feifei Shi, Jiangyan Wang, Rufan Zhang, Guangxu Chen, Yang Jin, Tong Wu, Zhiyong Tang, Yi Cui “Membrane-Free Zn/MnO2 Flow Battery for Large-Scale Energy Storage
” 31 january 2020 available: https://onlinelibrary.wiley.com/doi/full/10.1002/aenm.201902085?casa_token=0AMZ3v9U9VsAAAAA%3A2sl4j2Lsj6qGjoQzYSj_WQF1NROWCqqC3Lftwe yHjIWU_G61q8EiZEywMai2oz7VB2Zh5WyK0nlk [Accessed 2024/03/04]

[4] Zhengxin Zhu,Taoli Jiang,Mohsin Ali,Yahan Meng,Yang Jin,Yi Cui,Wei Chen, “Rechargeable Batteries for Grid Scale Energy Storage

” September 23, 2022, Available:https://pubs.acs.org/doi/full/10.1021/acs.chemrev.2c00289?casa_token=o7BshP82FZ8AAAAA%3AU_i2Xuhv6yqJMIwfLAgB3DP_x5V hLrz9ZxbSKL-Jkfbt90ToJJ9CC-_Erl1XNG8PWyUf9PGp9ejHAg