State of The Art and Future Trends for All-Iron Flow Batteries: a Comparative Analysis with Vanadium Flow Batteries for Large Scale Energy Storage

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IFBF

In the evolving scenario of flow battery technologies, the all-iron flow batteries (AIFBs) have attracted much attention and are currently being developed for grid scale energy storage. In terms of critical raw materials and geopolitical concerns, the use of inexpensive and abundantly available iron makes AIFBs an attractive option, potentially capable to contribute to a more secure and resilient supply chain. This is in contrast to vanadium, which is less abundant, expensive and not produced in Europe at present. The potential competitiveness of AIFBs, with an estimated cost of 200 – 300 €/kWh, makes them an attractive option for large-scale energy storage. However, several challenges need to be addressed, for example, the irreversible capacity decay due to hydrogen evolution, and lower power density if compared to vanadium flow batteries (VFBs). This poster aims to provide an overview of the current state of AIFB through a comparative analysis with VFBs, in terms of performances and costs. In particular, two types of AIFBs will be investigated: all-iron hybrid flow batteries (AI-HFB), characterized by the iron plating reaction at the anode, and iron flow batteries with no deposition reactions, named all-liquid all-iron flow batteries (all-liquid AIFBs).

Table 1: VFB, AI-HFB and all-liquid AIFB performance comparison.

Battery Type	OCV [V]	Current density [mA/cm²]	CE %	VE %	EE %	Capacity Fade [%/Cycle]	Estimated cycle life	Specific Energy Density [Wh/L]	Drawbacks	Ref.
VFB	1,26	120	99	74	73	0,0931	20000	25	High cost, use of critical raw material.	[1]
AI-HFB	1,21	30	99	76	75	0,0064	20000	24,5	Low current density, hydrogen evolution, use of rebalancing systems, plating/stripping reaction, dendrites formations.	[2]
All-liquid AIFB	1,19	80	99	84	83	0,0177	N.D.	23,5	Use of different electrolytes, no information about the regeneration process.	[3]

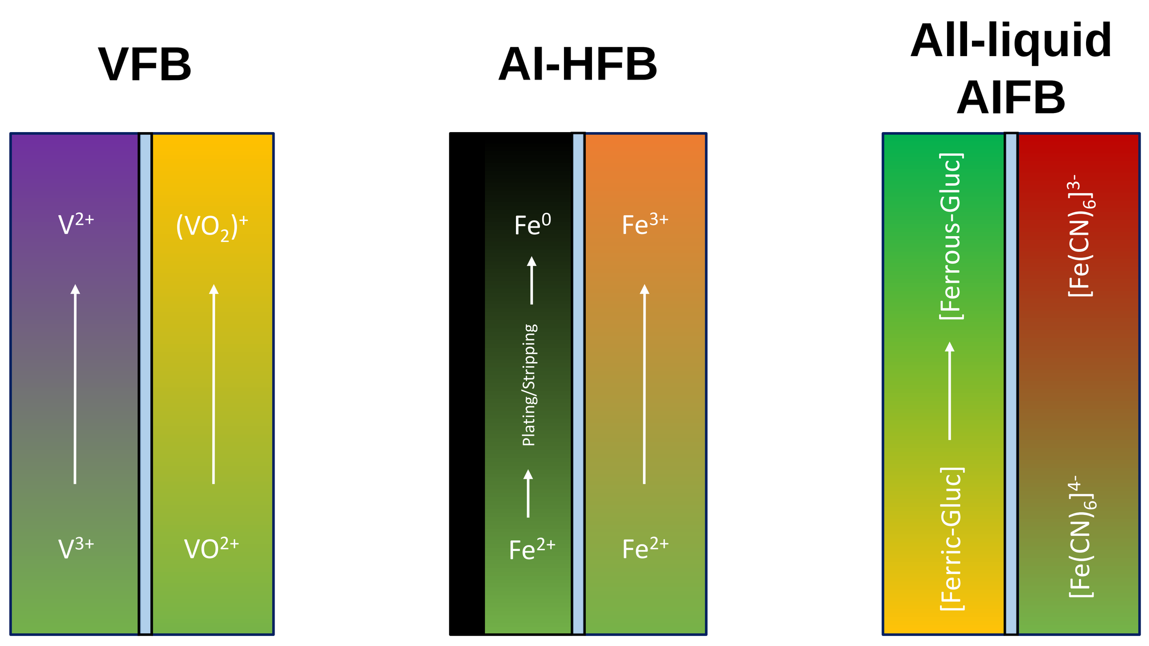


Figure 1: VFB, AI-HFB and all-liquid AIFB anode and cathode reactions.

- The deposition/dissolution reaction of AI-HFBs can be enhanced with proper solvents, like DMSO.
- Ligands, like glycine, can be used to maintain the solubility of Fe (III) up to pH of 3 [4].
- Regeneration processes can be use to rebalance the electrolyte after undesired hydrogen evolution reactions [5].

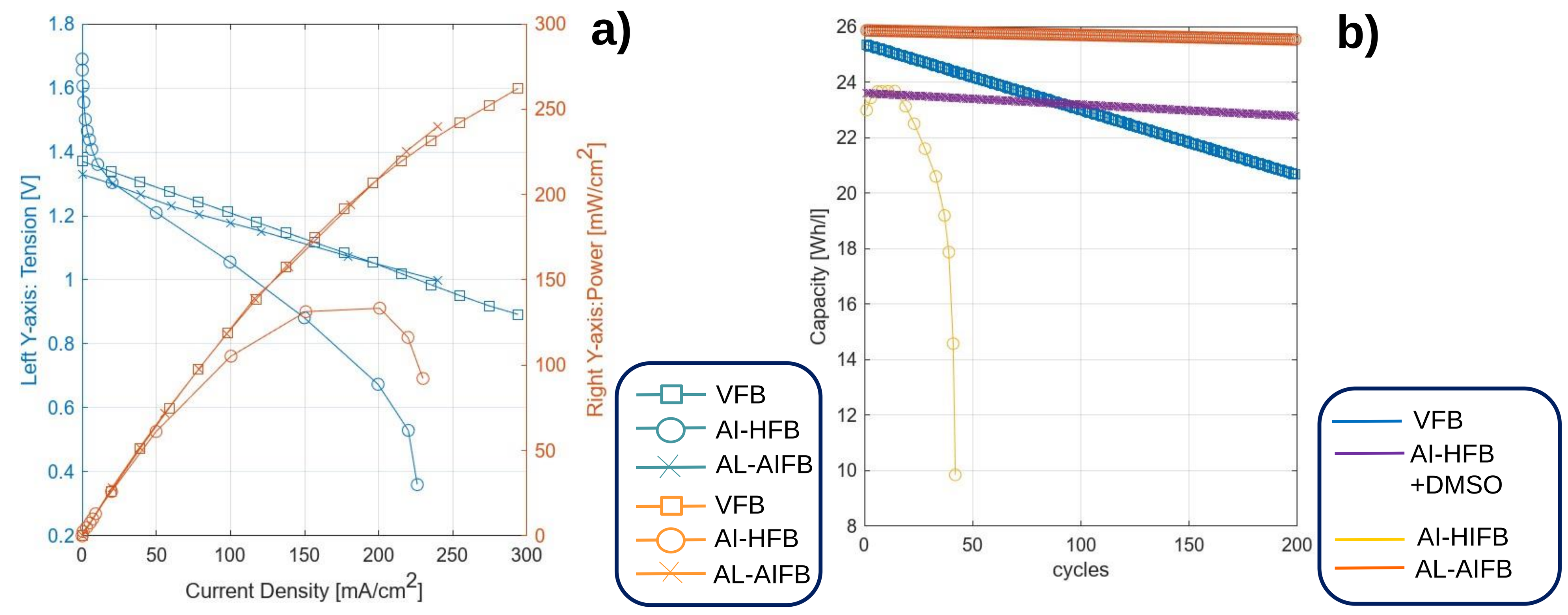


Figure 2: Characteristic curves of the aforementioned flow batteries. a) Polarization and power curves. b) Capacity fade of the batteries.

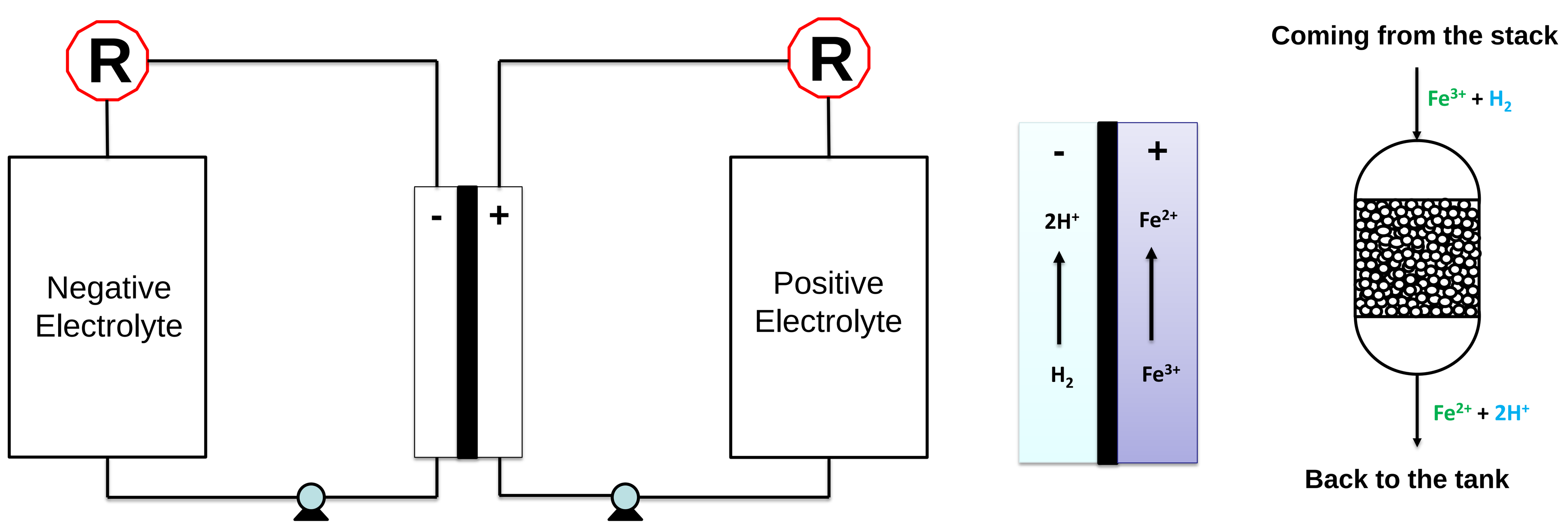
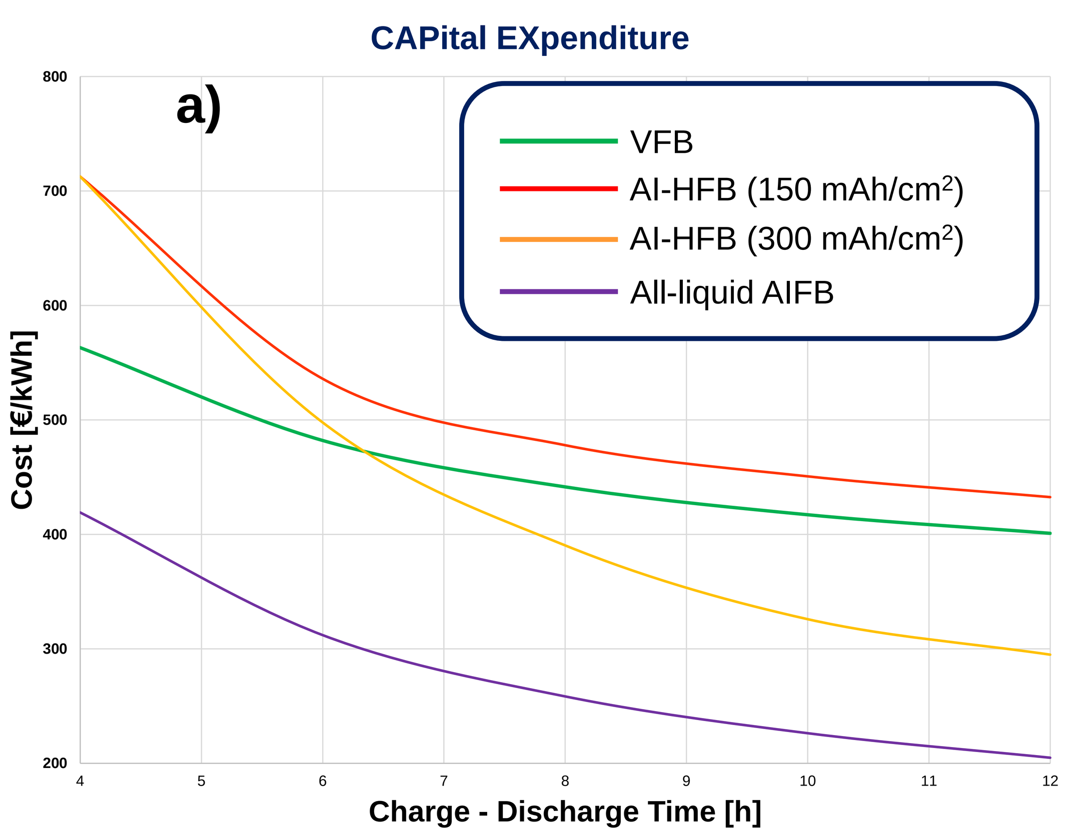


Figure 3: Scheme of the regeneration processes for AI-HFBs [6].

Using data taken from industrial size plants and literature [7], the CAPEX of AIFBs was investigated and a techno-economic comparison with VFBs was performed. The main components affecting the capital costs were considered. Relevant economic parameters were taken from real market data. The comparison considered systems with a rated power of 1MW and a discharge duration ranging from 4 to 12 hours. Results suggest that traditional AI-HFBs, despite the low cost of the electrolyte, are competitive only for high plating densities (300 mAh/cm²) [8]. The all-liquid AIFB results cheaper than other solutions also for short discharge times. Further investigations are needed to assess the all-liquid AIFB cycling capacity, regeneration processes and electrolyte disposal.



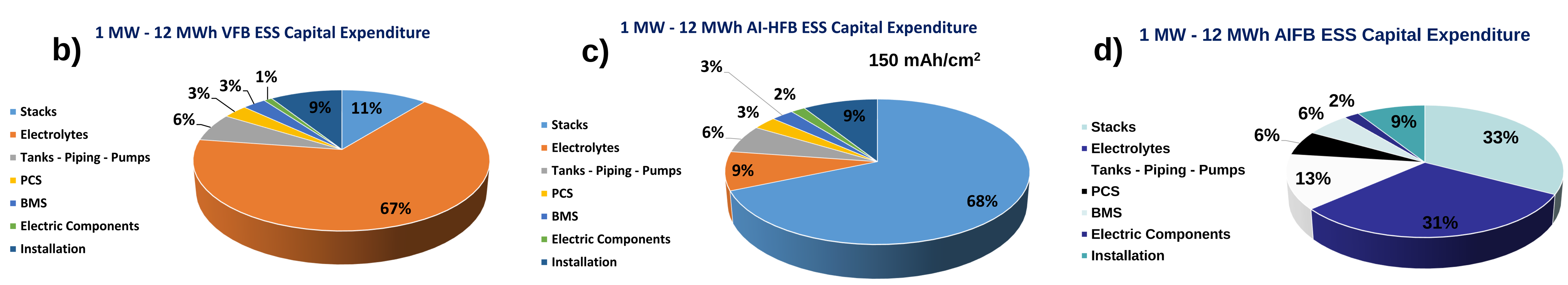


Figure 4: a) Capex of VFB, AI-HFB and all-liquid AIFB. Battery system cost percentage of: a) VFB; b) AI-HFB (150 mAh/cm²) and c) all-liquid AIFB.

Conclusions

In VFBs, 66% of the cost is given by the electrolyte. Conversely, in AI-HFB 68% of the costs is in the stacks, because stacks with 70 cells are needed to compensate the low current density (30 mA/cm²). In addition, an oversized stack is needed to compensate for the low specific plating density (150 mAh/cm²). The analysis shows that, if a plating density of 300 mAh/cm² was reached, the AI-HFB could be profitable for discharge durations above 6.2 h. In all-liquid AIFBs, the higher current density (80 mA/cm²) and the absence of deposition may drop the system cost down to 300 €/kWh and 200 €/kWh for 6 and 12 hours of discharge respectively.

Further performance improvements and cost reductions can come from the perspective adoption of “universal flow battery” technological advancements. See the oral presentation in this conference.

References

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