Cost and performance targets for competitive aqueous organic redox flow battery systems

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Objectives

1. Develop a comprehensive **cost model** for FBs
2. Find the **key technical** and **economical variables** of the AOFB capital cost
3. **Design low-cost** AOFBs

INTRODUCTION

- **Redox flow batteries** are a promising but still **developing technology**, and there is a high uncertainty around their cost and performance in real-case scenarios.
- Vanadium Flow Batteries (VFBs) have shown commercial success but face limitations in cost and sustainability, having a current price of about 500 $ kWh^{-1}.
- The target is to make long-duration utility-scale storage, using low-cost organic materials to build **Aqueous Organic Flow Batteries** (**AOFBs**), with a target capital cost of 150 $ kWh^{-1}.
- The study identify and optimizes the value of key AOFB variables to obtain **cost-effective** systems and guide future research towards their development.

METHODS & DATA

The total capital cost of FBs is evaluated with a bottom-up model that includes all the **energy** and **power-related costs** of the battery. The model considers **design parameters** such as **open circuit voltage (OCV), efficiency (RTE), current density (i_d)**, and **cost of materials** for different organic battery configurations.

The method involves analyzing the capital costs of a VFB and a FcVi FB, followed by the design of various AOFBs. **Target values** are identified to reduce the capital cost to **150 $ kWh^{-1}** (127 € kWh^{-1}).

The key parameters for the **real** (VFB and FcVi) and **designed** (AOFB I, AOFB II, and AOFB III) FBs are showed in Table 1.

Other FBs characteristics: 40 cells in series; active area of 600 cm^2.

Table 1 Name, unit and value of key parameters used to calculate the capital cost of VFB, FcVi, AOFB I, II and III [2,3]

Parameter	Unit	VFB	FcVi	AOFB I (V target)	AOFB II (Low-cost target)	AOFB III (Low-cost target)
OCV	V	1.37	0.72	1.25	1.37	1.5
i_d	$mA\ cm^{-2}$	85.8	24.2	49.2	85.8	125
RTE	%	74.3	54.2	81.4	74.3	82
$conc_{act}$	$mol\ L^{-1}$	1.6	0.5	0.5	1.6	2
ASR	$\Omega\ cm^2$	1.35	4	1	1.35	1
$SoC\ range$	–	0.6	0.4	0.4	0.6	0.6
t_d	h	4	4	4	9	9
$SB\ t_d$	h	0	0	0	8	0
c_{active}	$\$\ kg^{-1}$	30.1	3.5	3.5	3.5	3.5
$c_{membrane}$	$€\ m^{-2}$	300	300	53	53	300
c_{felt}	$€\ m^{-2}$	53	53	9	9	53
c_{BP}	$€\ m^{-2}$	100	100	18	18	100
C_{tot}	**$€\ kWh^{-1}$**	**450**	**1800**	**450**	**127**	**127**

RESULTS

Even assuming **low-cost organic molecules (3.5 $ kg^{-1})**, the capital cost of aqueous organic batteries such as the FcVi FB is still **several times higher** than the costs of VFBs, as shown in Figure 1.

The cost of a VFB is 450 € kWh^{-1}, while the cost of a FcVi FB is 1876 € kWh^{-1}, for 4h FBs. The active material cost's contribution to the battery's total cost is minimal. Even assuming a zero active material cost, the FcVi battery still remains high at 1716 € kWh^{-1}.

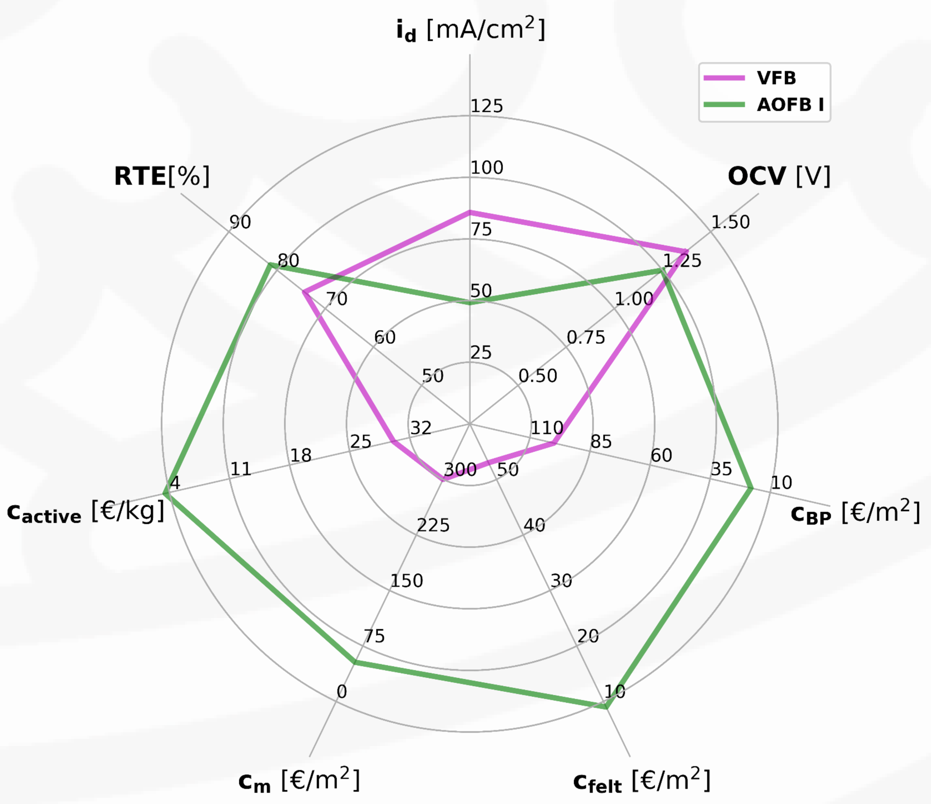

Figure 2 Radar plot with key features for FBs with a target cost of 450 € kWh^{-1}.

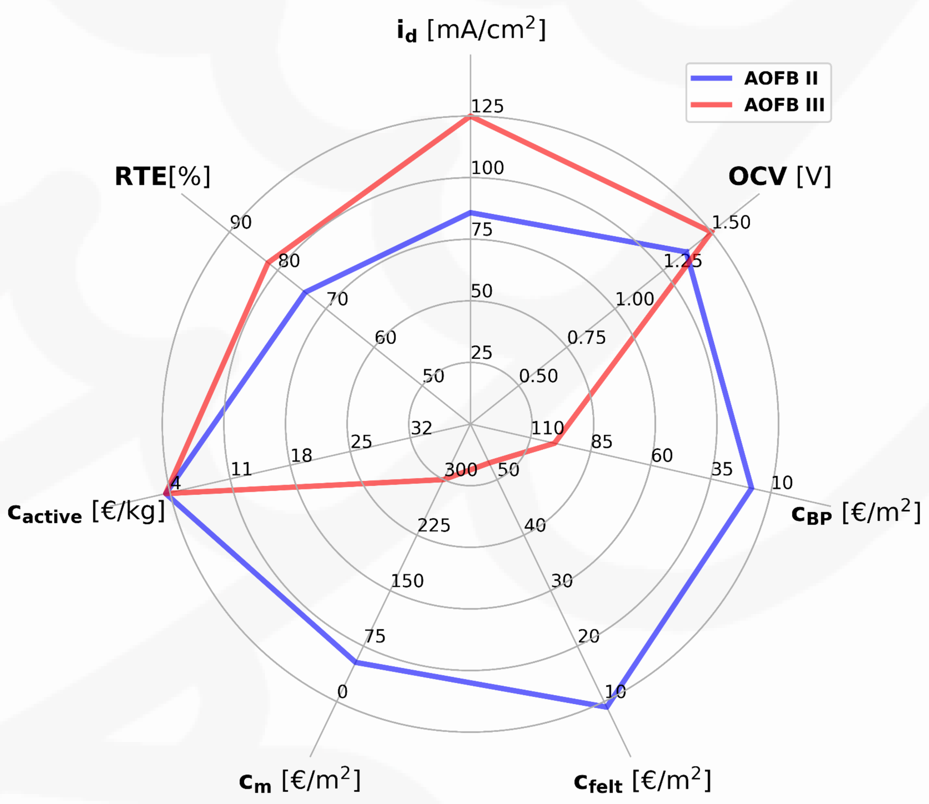

Figure 3 Radar plot with key features for FBs with a target cost of 127 € kWh^{-1}.

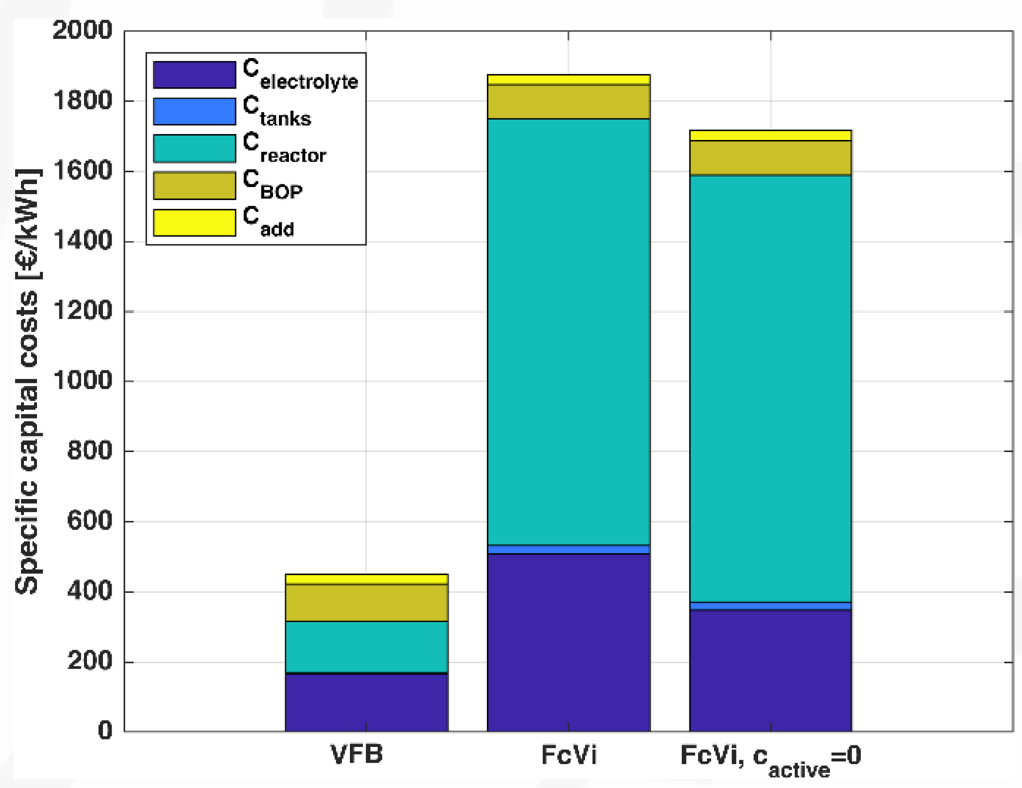

Figure 1 Capital costs breakdown for FBs with 4h discharge time - VFB, FcVi, and FcVi without the cost of active material.

This high cost of the FcVi organic battery stems from **low values of OCV, concentration,** operational **current density**, and overall **battery efficiency**.

Figure 2 shows the key parameters of **VFB** and **AOFB I**, with a capital cost of 450 € kWh^{-1}, while Figure 3 shows **AOFB II** and **III**, two alternative FB designs with a capital cost of 127 € kWh^{-1}.

CONCLUSIONS

- The study identifies and optimizes the **key design FB parameters** to achieve a competitive capital cost.
- AOFBs could offer cost-competitive expectations for long-duration energy storage applications.
- However, to be economically viable, it is important to **enhance the properties of current AOFBs**, and find a balance between technical performance and materials cost.

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