HIGREEW

# Workshop -Flow batteries, bringing the technology to the market

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## Modular balance of plant for mass-customized flow battery production

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*Fraunhofer ICT*

*2023-05-17*

*The research leading to these results has received funding from the European Union under Grant Agreement no. 875613*

# Redox Flow Batteries: container village vs. centralized plant

**Source:** https://www.energy-storage.news/invinity-to-deploy-vanadium-flow-battery-at-solar-plus-storage-project-in-alberta-canada/
*Invinity Energy Systems*

Cost effectiveness

**vs.**

Flexible Scalability

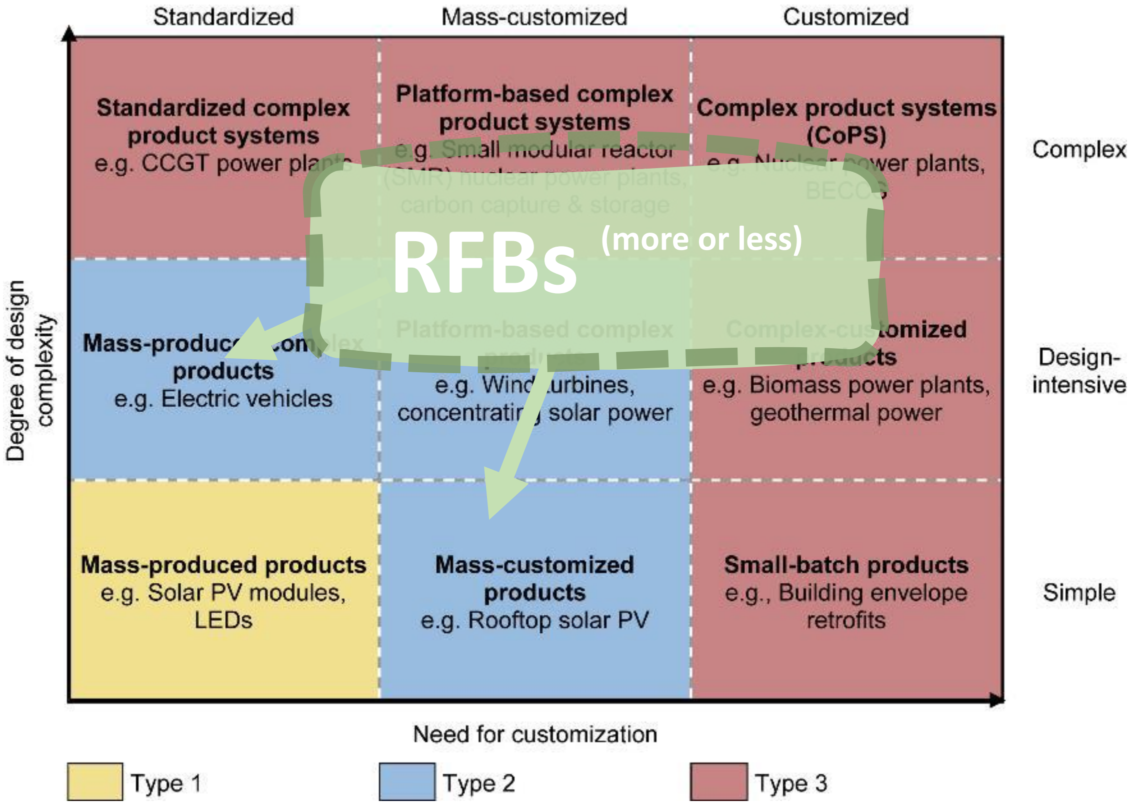
*RFB Installation © Fraunhofer ICT*

# Redox Flow Batteries must be mass producible!?

Malhotra, Schmidt (2020):

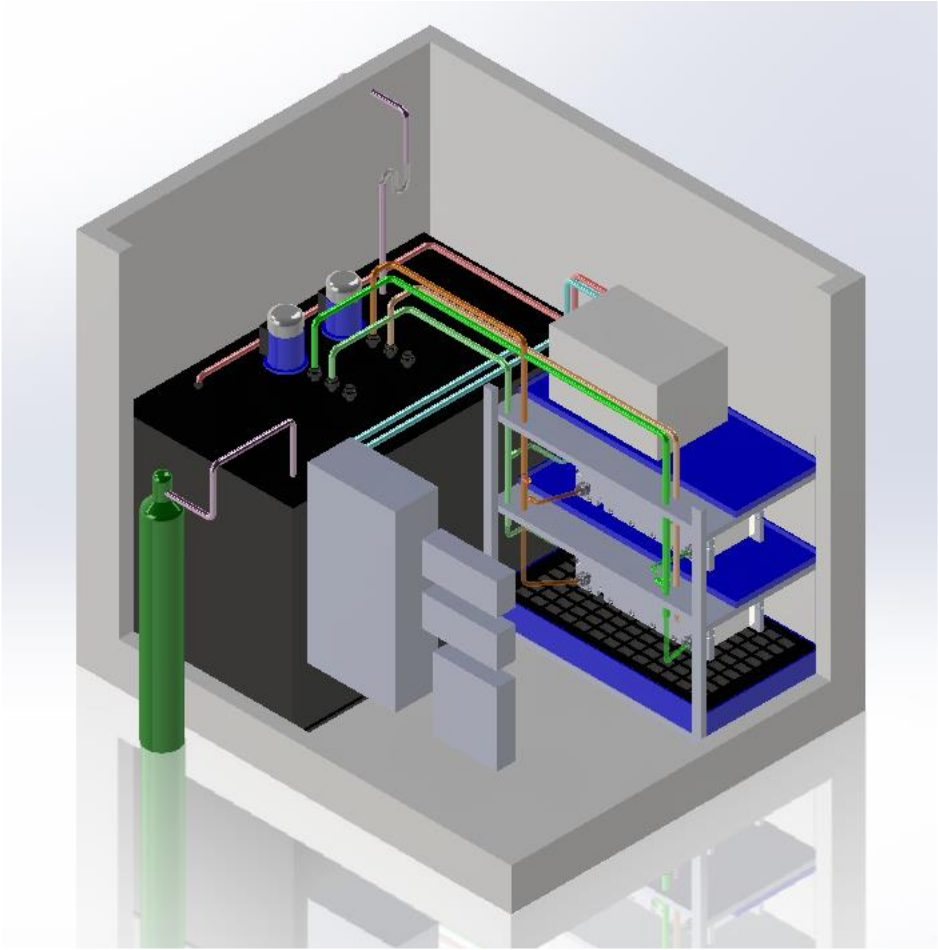
- *"[high complexity] technologies (…) have progressed in isolated niches but not at a global scale"*
- *"national green industrial policies have thus far played an important role in supporting innovation in Type 2 technologies and are likely to also do so in the future"*

➔ While scaling flexibility is a big strongpoint of RFBs, highly customized plants could be counter-productive in terms of cost reduction

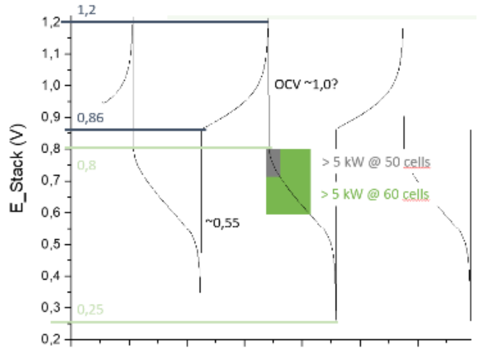



**Source:** Malhotra, et al., "Accelerating Low-Carbon Innovation", 2020
https://doi.org/10.1016/j.joule.2020.09.004

# HIGREEW Prototype History



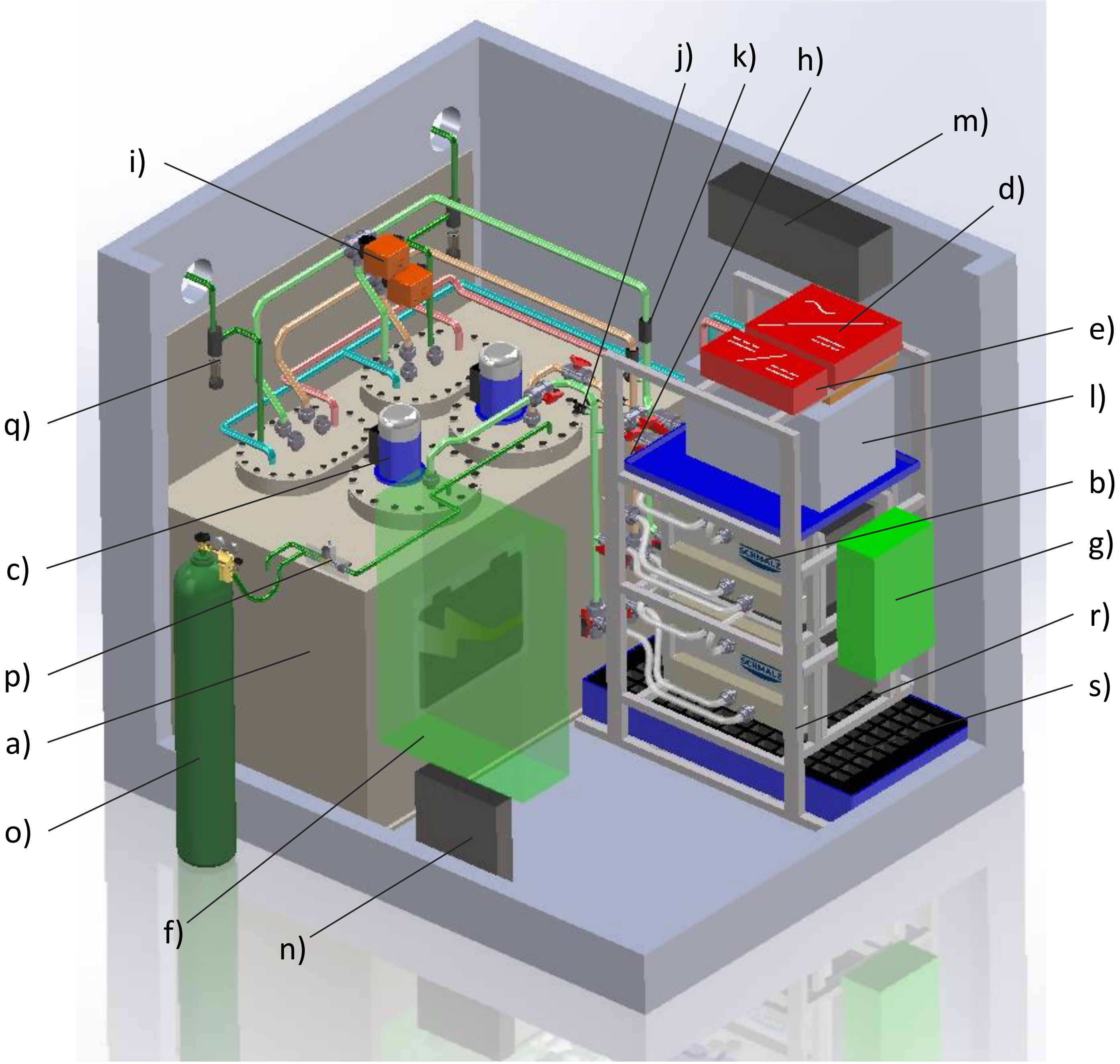
AORFB: scale up from laboratory cell to kW-scale prototype system




← **Mar 2022**

→ Simple BOP design ✓

→ Main components defined ✓




# HIGREEW Prototype History

## ← Aug 2022

a) Double-walled tank with heat exchangers and level / temperature probe and leakage detection
b) Stacks
c) Vertical centrifugal pumps
d) DC/AC inverter
e) DC/DC converter
f) BMS / Control cabinet
g) Secondary electrical cabinet
h) Piping system with valves, sensors (e.g., temperature, SOC)
i) Motorized mixing valves
j) Pressure sensors
k) Flow sensors
l) Chiller
m) Air conditioner (interior unit)
n) Heater
o) Inert gas (nitrogen) cylinder
p) Inert gas pressure control valve and pressure release
q) Oil trap and gas release
r) Stack rack
s) Spill tray with leakage sensor

# HIGREEW Prototype History

## Mar/Apr 2023

- Container plugged into grid and ready for operation ✓

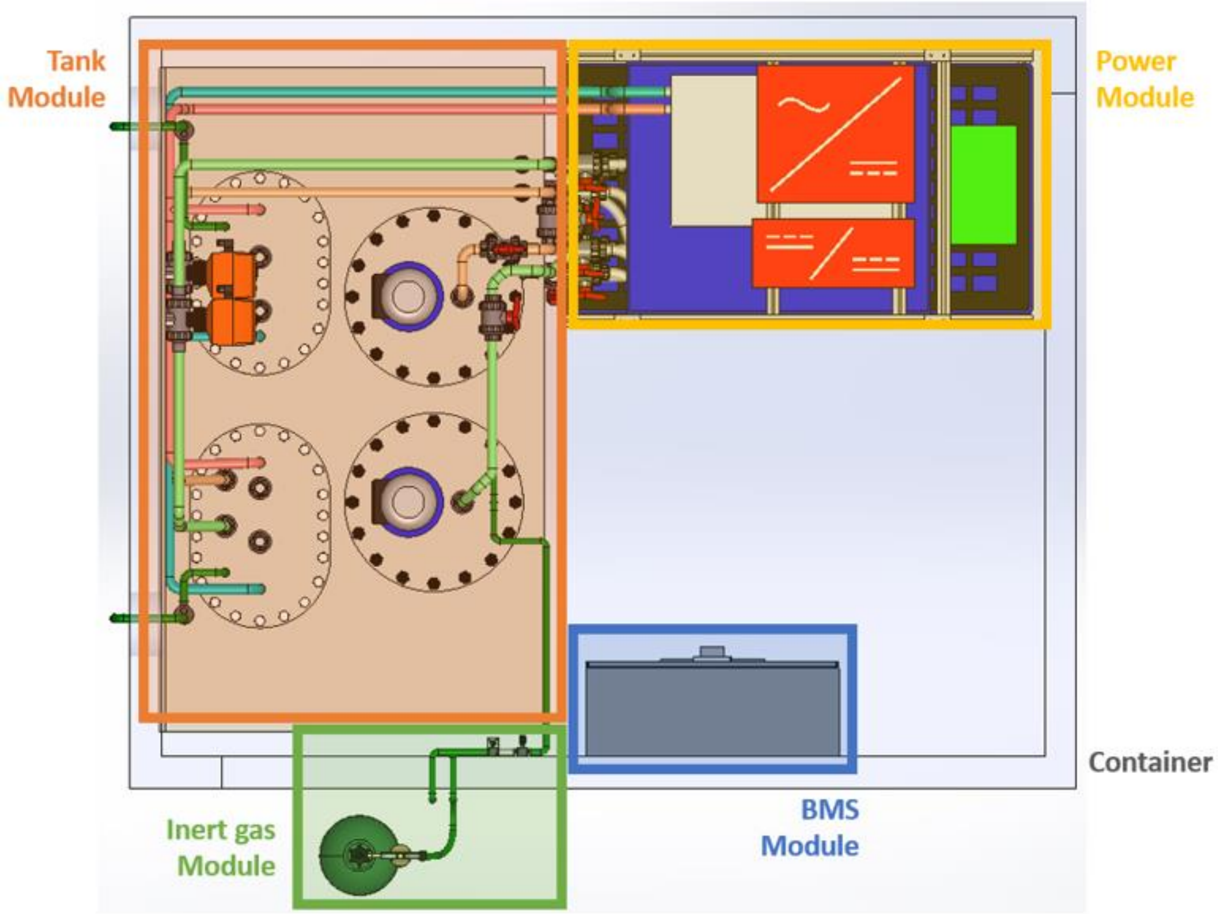
"La Plana Hybrid Facility"
**Source:** SGRE

# Prototype: Modular BOP

## Challenges:
(apart from the technical challenges …)

- Tight schedule ⚠ Long lead times / Shipping delays
- Limited space available: Compact design
- Logistical difficulties: Fast (dis)assembly required

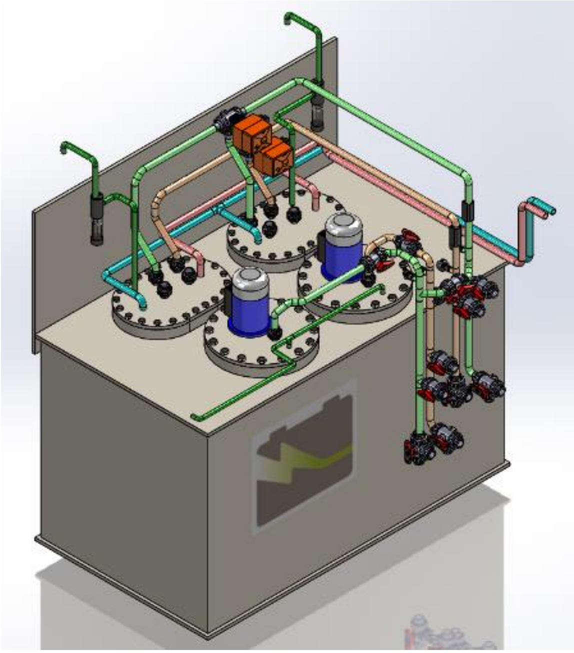
→ Sub-division of prototype in ***5*** building blocks (modules)



# Prototype: Modular BOP

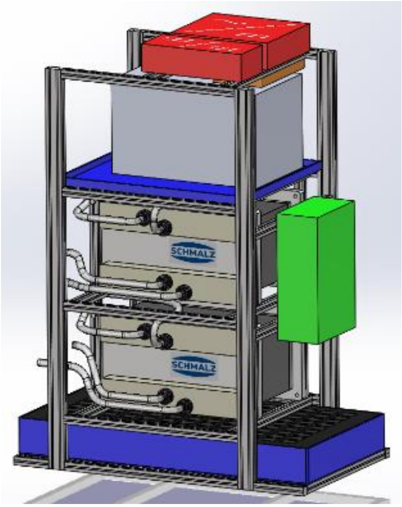
## Tank Module (Capacity)

- Tank
- Pumps
- Pipes, valves, sensors
- OCV cell



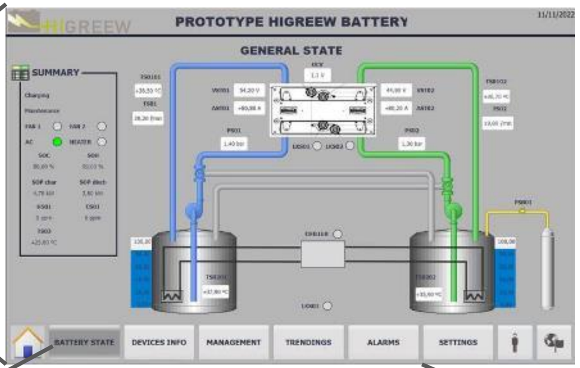
## Power Module

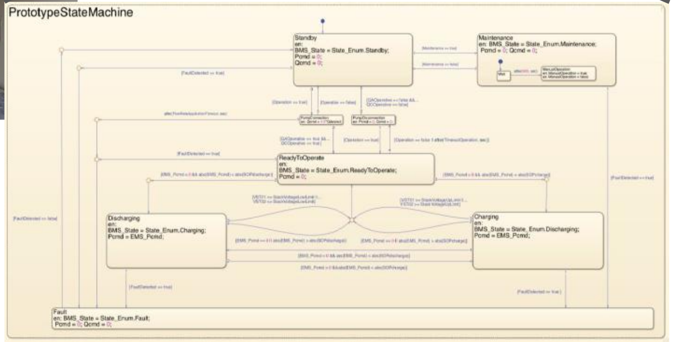
- Stacks
- Inverter
- (Cooling system)



# Prototype: Modular BOP

## BMS Module




## Container

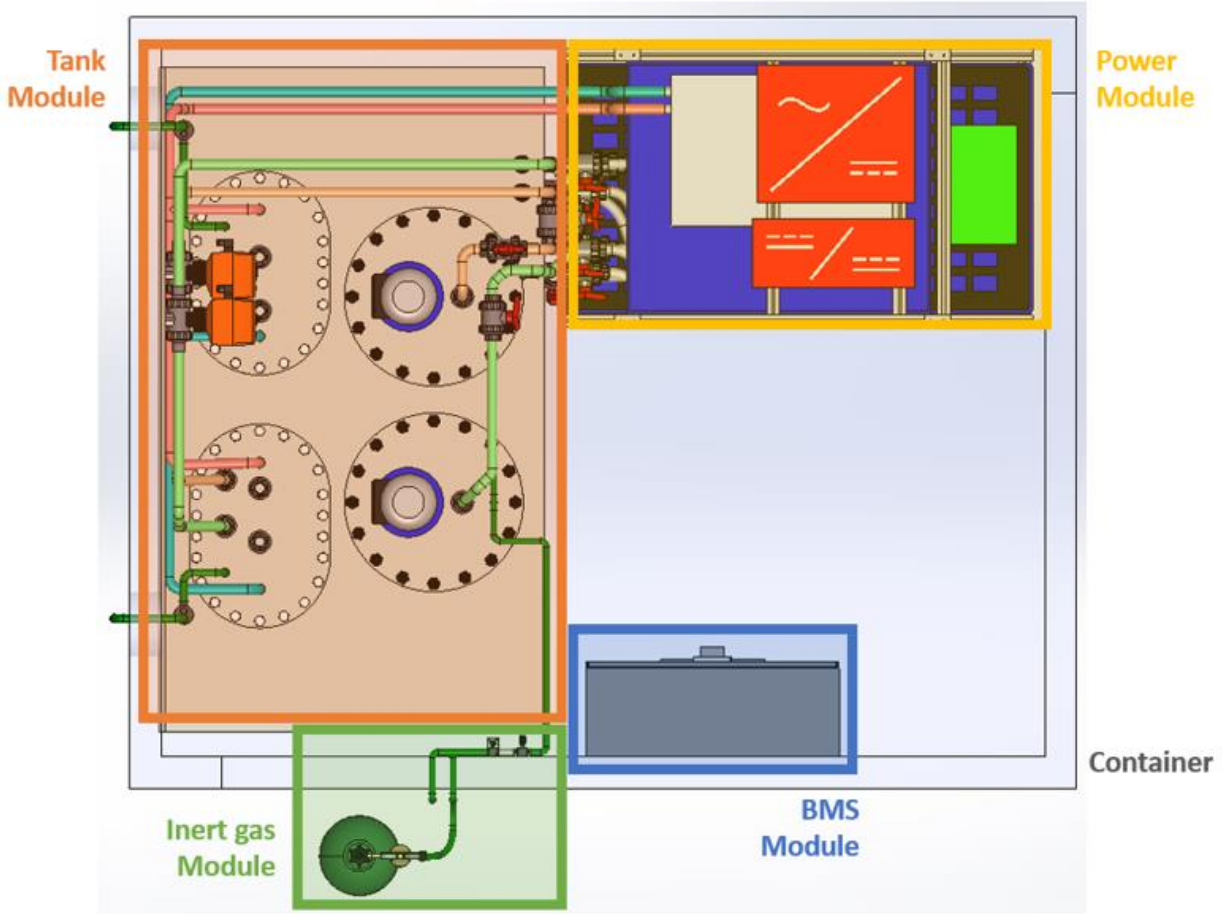

## Inert Gas Module

# Prototype: Modular BOP

## Interfaces:

| | Power module | Tank module | BMS module | Inert gas module |
|---|---|---|---|---|
| **Tank module** | • Stack tubes (tube nozzles)<br>• Cooling water pipes (screwed union connection) | | | |
| **BMS module** | • Power cables<br>• Signal and power supply cables voltage, current, leakage sensors<br>• Communication cable (RJ45) | • Power cables pumps, valves<br>• Signal and power supply cables temperature, pressure, flow, level, leakage | | |
| **Inert gas module** | | • Gas pipes (screwed union connection) | • Signal and power supply cable pressure control valve | |
| **Container** | • Mechanical connection (Floor and wall) | • Mechanical connection (Walls)<br>• Exhaust pipes through back wall cut-outs | • Mechanical connection (Wall)<br>• Electrical connections appliances, lighting<br>• Mains connection through side wall cut-out<br>• Signal and power supply cables room temperature and gas sensors | • Mechanical connection (valves inside, gas cylinder outside wall)<br>• Supply and pressure release pipes through side wall cut-out |

Connections: Pipes Power Data Mechanical



# Prototype: Modular BOP

## Modular design to facilitate…

- … testing of individual components in lab environment
  → for early testing
- … dis- and reassembly of battery
  → for quick container installation
- … scale-up considerations
  → for LCA, LCOS analyses

Prototype setup in the lab →

Finished container system →

# Prototype: First experience

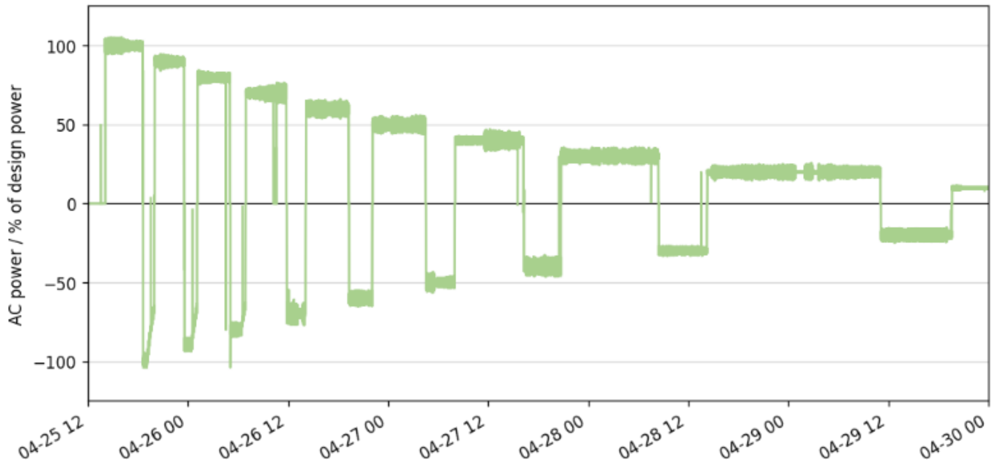
## Commissioning in “La Plana”:

- Container set-up, filling of electrolyte
- Final functionality testing
- Fine-tuning of algorithm parameters → “state of power” estimation for different flow rates, SOC



## After commissioning:

- System has been running continuously for > 3 weeks, with ~ 1 cycle / day
- So far no degradation of electrolyte observed, no significant cross-over or capacity loss



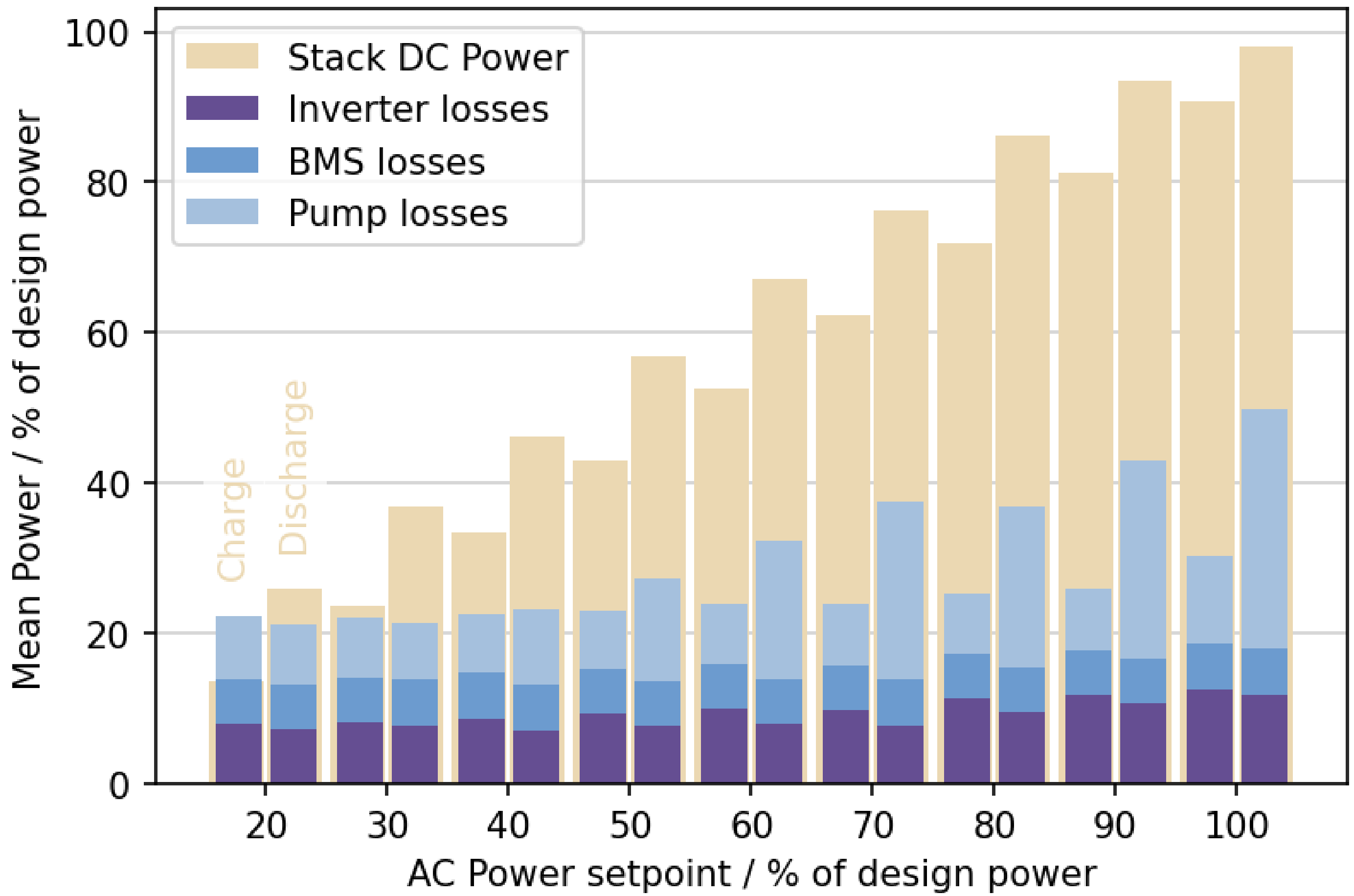
# System performance

## Difficulties after one week of commissioning:

- Fault in stack #1 → For the moment system is only being operated with one stack (2.5 out of 5 kW total)
- Temperature was still quite low in the beginning and only went up slowly

→Difficult to assess system efficiency:

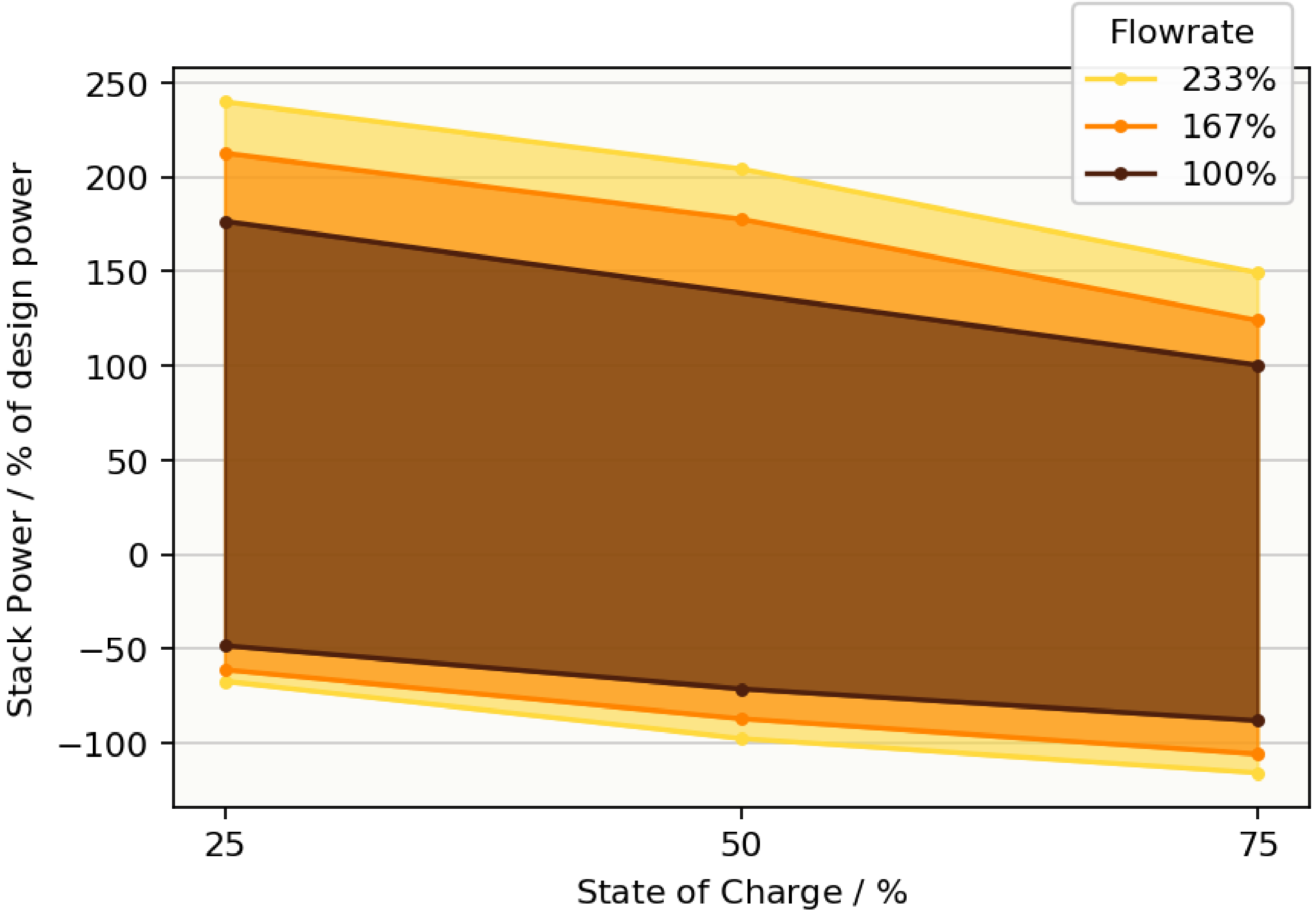
- Pumps and inverters less efficient for only one stack
- Other auxiliaries (incl. BMS) have higher impact on total system losses



# Stack performance

## Stacks:

- Design by scale-up of laboratory cell performance values
  → $P_{nom}$ = 2.5 kW (per stack)
- Manufacturer: *Schmalz GmbH* (Germany)
- Constructed with active components identified by the partners in HIGREEW project

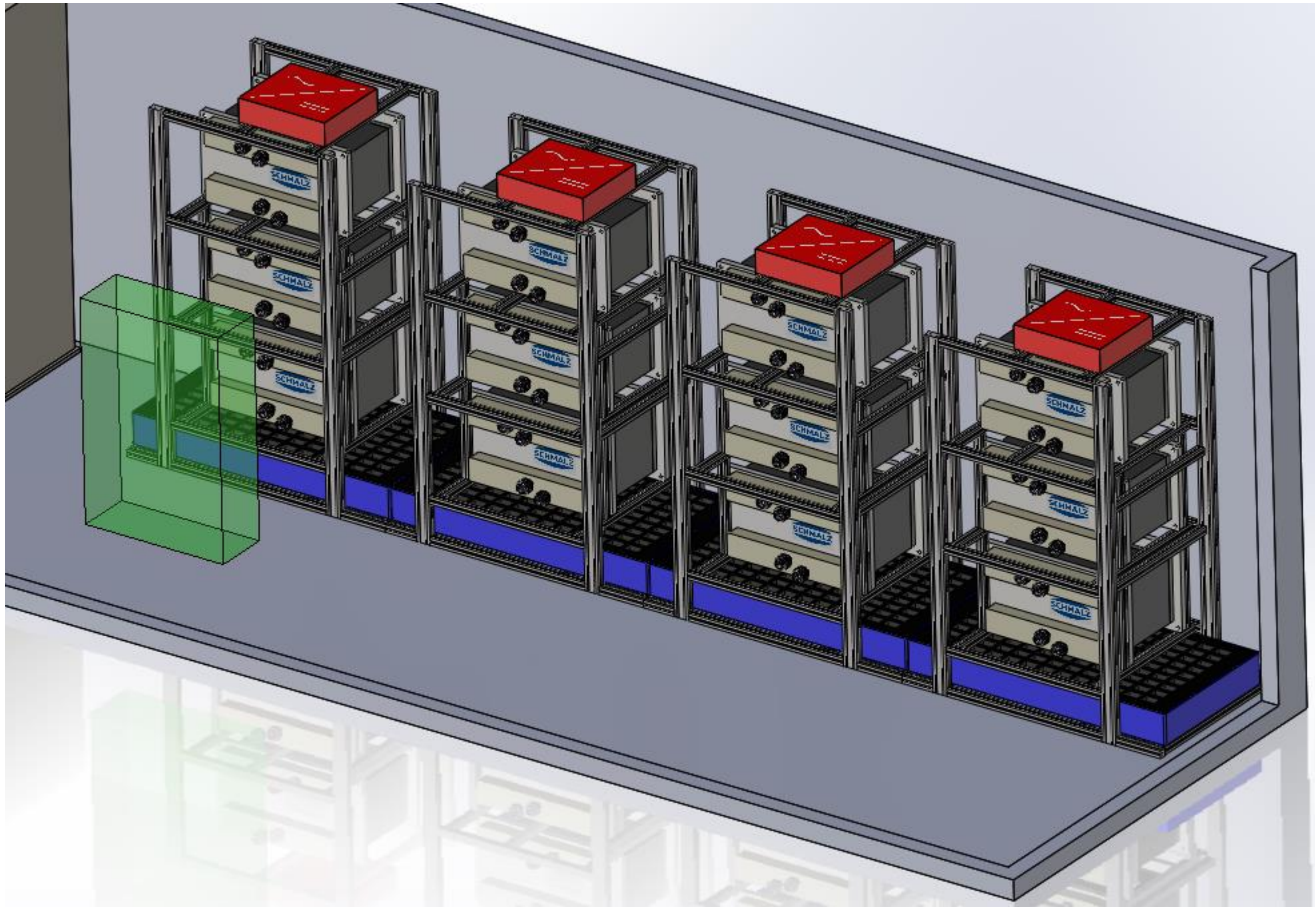


# Lessons learned

## Modular design to facilitate…

- … testing of individual components in lab environment
  - →e.g., for quality insurance, or R&D: "Hardware in the loop" simulation
- … dis- and reassembly of battery
  - →e.g., to streamline production processes ("standard" + "optional equipment"), standardization
- … scale-up
  - →e.g., for automation, mass production

➔ "Mass customized" RFB production for flexible power to energy scaling



# Summary / Next steps

Biggest technical challenge: Scale-up of new RFB chemistry from lab to kW-scale prototype without intermediate steps

Biggest organizational challenge: Coordinating inputs from different partners while navigating through difficult market situation (supply chain issues)

Next up: Prototype to generate data in real environment

Lessons learned: Modular BOP Design can help to standardize / streamline assembly processes

# Thank you!

*The research leading to these results has received funding from the European Union under Grant Agreement no. 875613*

# Disclaimer/ Acknowledgment



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 875613. The information and views set out in this publication does not necessarily reflect the official opinion of the European Commission. Neither the European Union institutions and bodies nor any person acting on their behalf, may be held responsible for the use which may be made of the information contained therein.