HIGREEW

First Project Workshop

In Pilsen and Online

HOW TO DESIGN & VALIDATE EFFICIENT AQUEOUS ORGANIC REDOX FLOW BATTERY CELLS

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Pinflow Energy Storage

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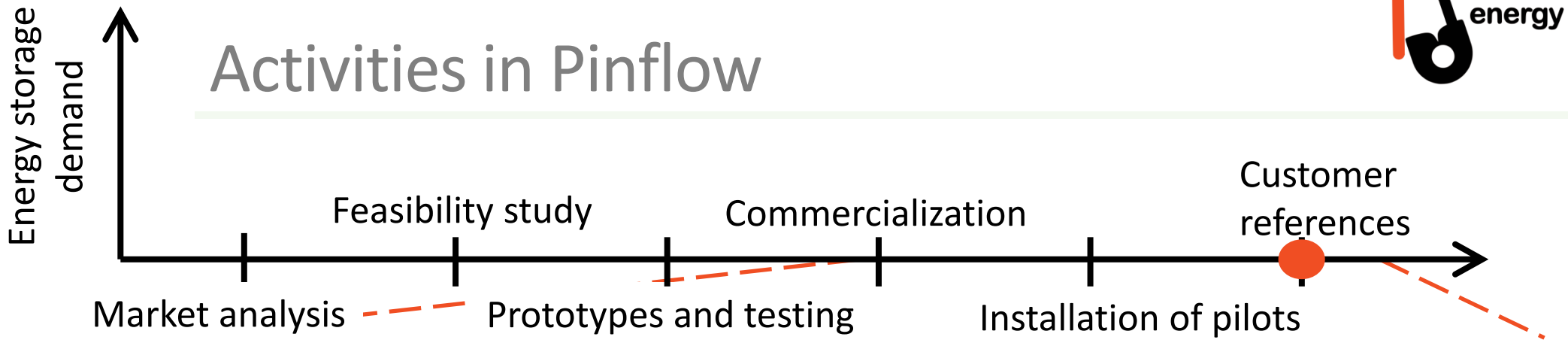
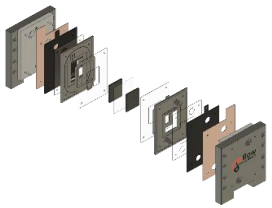
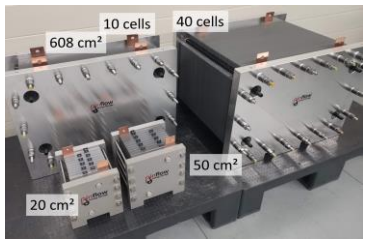
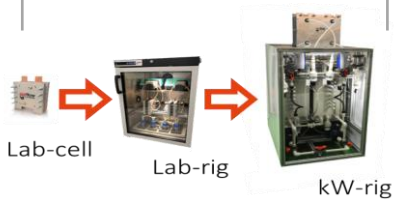
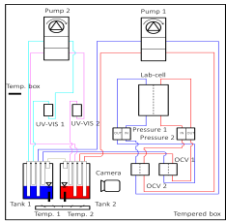
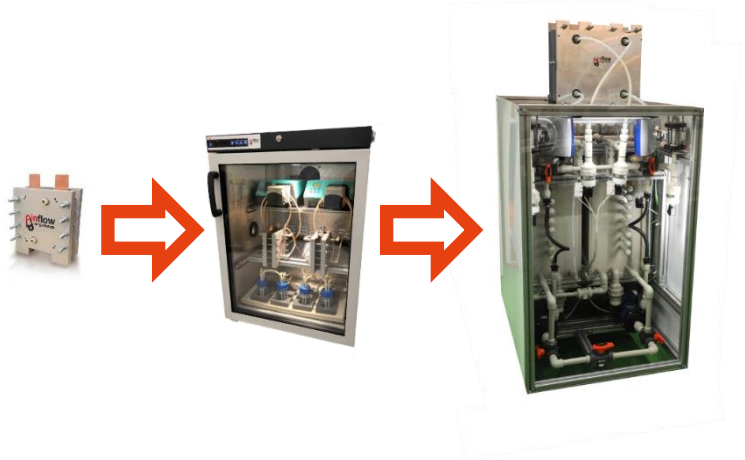
Activities in Pinflow



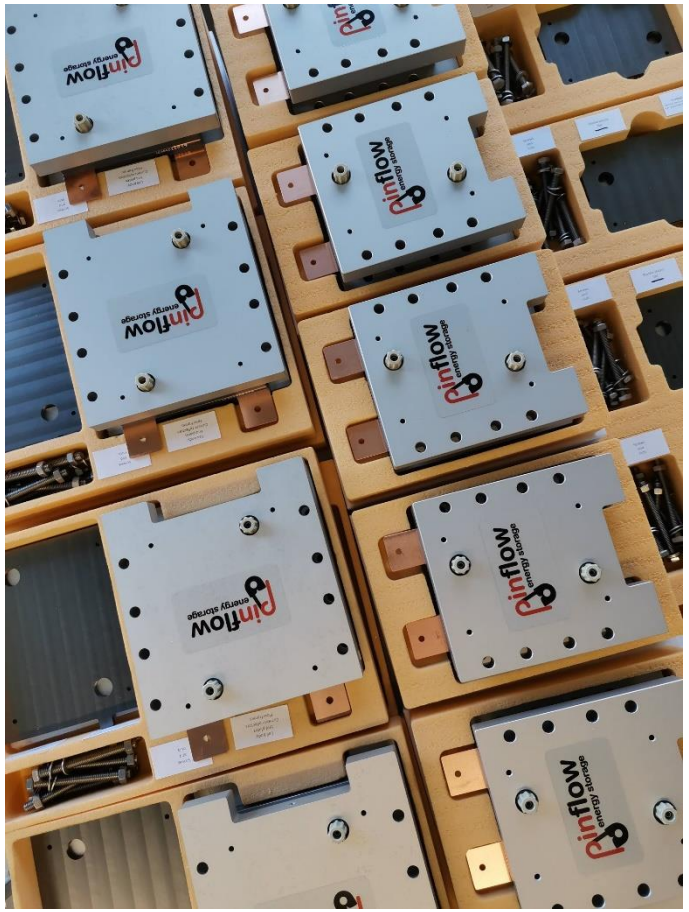
Continuous material screening and benchmarking	Stack upgrades, improvements and maturement to higher power and TRL	Research and development of new RFB technologies (H2020 projects)	Manufacture, sales and development of RFB labware	Development, deployment and manufacture of VRFBs
		HIGREEW HyFlow HYBRID ENERGY STORAGE SYSTEM	 	 
	100 % Constant annual growth rate	0 €, 0 % External venture funding and equity		

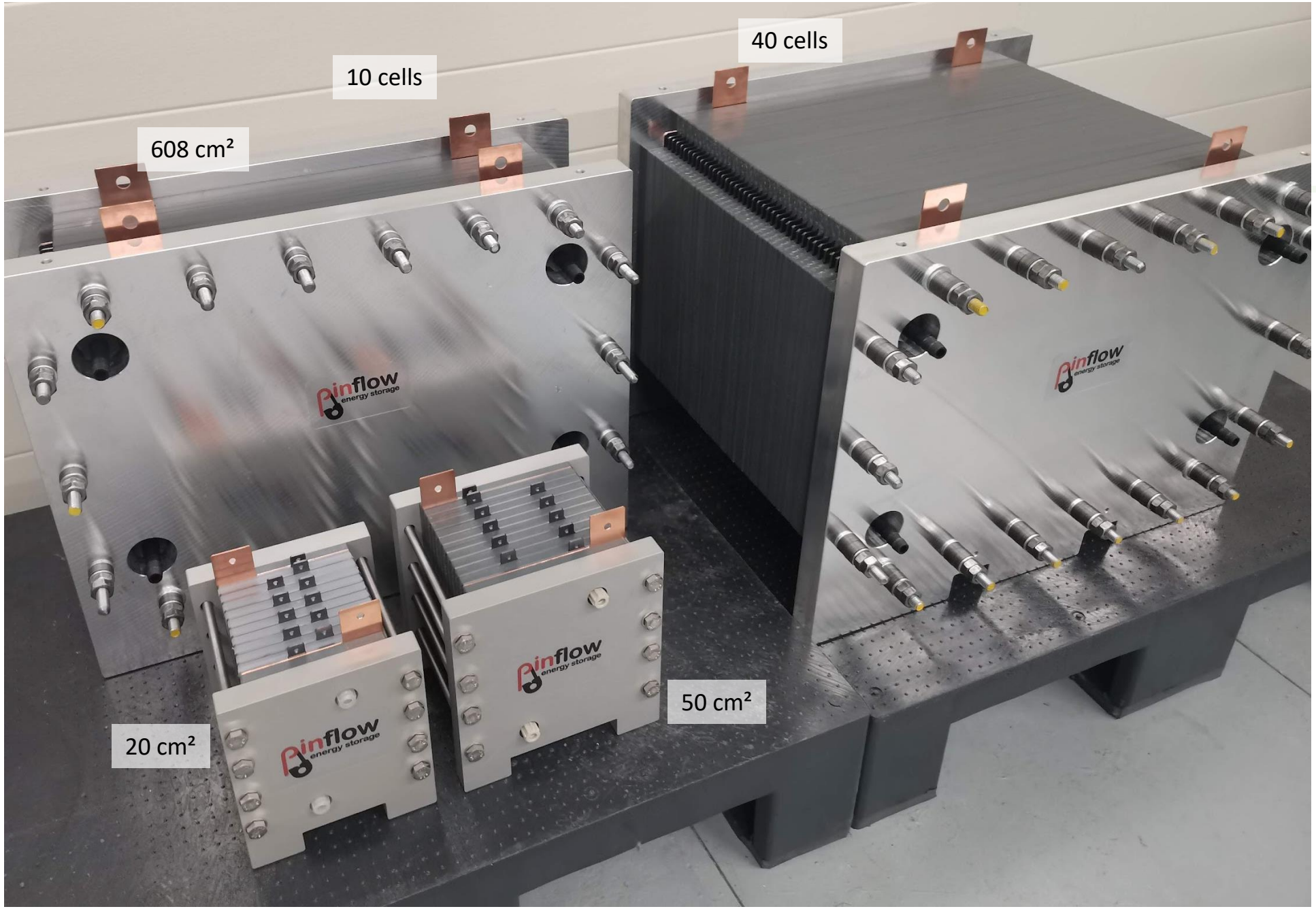
RFB research products

Research systems from lab-scale to kW-scale leading to commercial BESS



- Dozens systems installed worldwide
- Customers: R&D, QC of active materials
- The best reproducibility of measurement
- Own mechanical parts, electronics and software




40 cells
10 cells
608 cm²
50 cm²
20 cm²

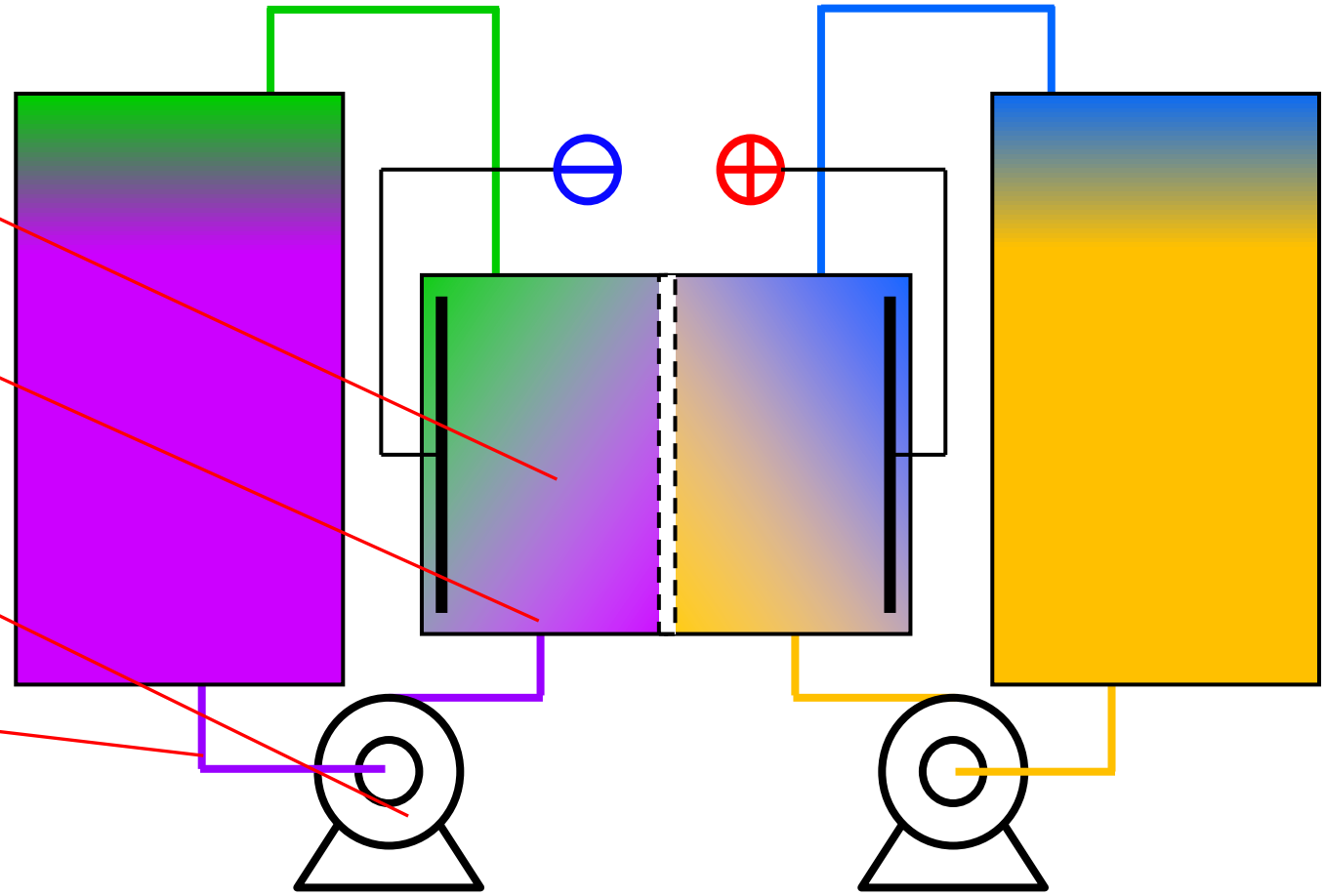
Introduction

Stack performace
+ high flow rate

Flow distribution
+ high flow rate

Pumping power
- high flow rate
+ short guide channels

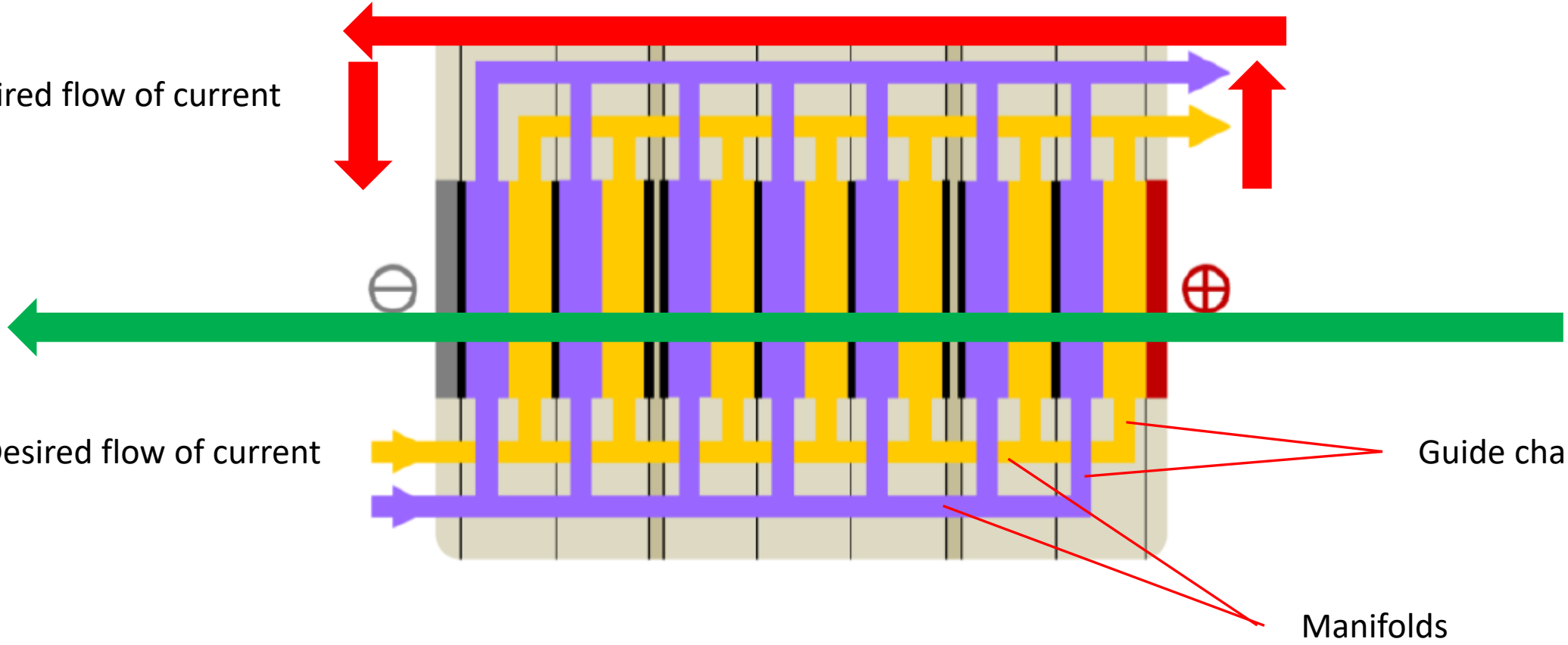
Shunt current
- short guide channels



Shunt currents

Electrolyte is ionically conductive - electrolyte circuit

Undesired flow of current



Desired flow of current

Guide channels

Manifolds

Models

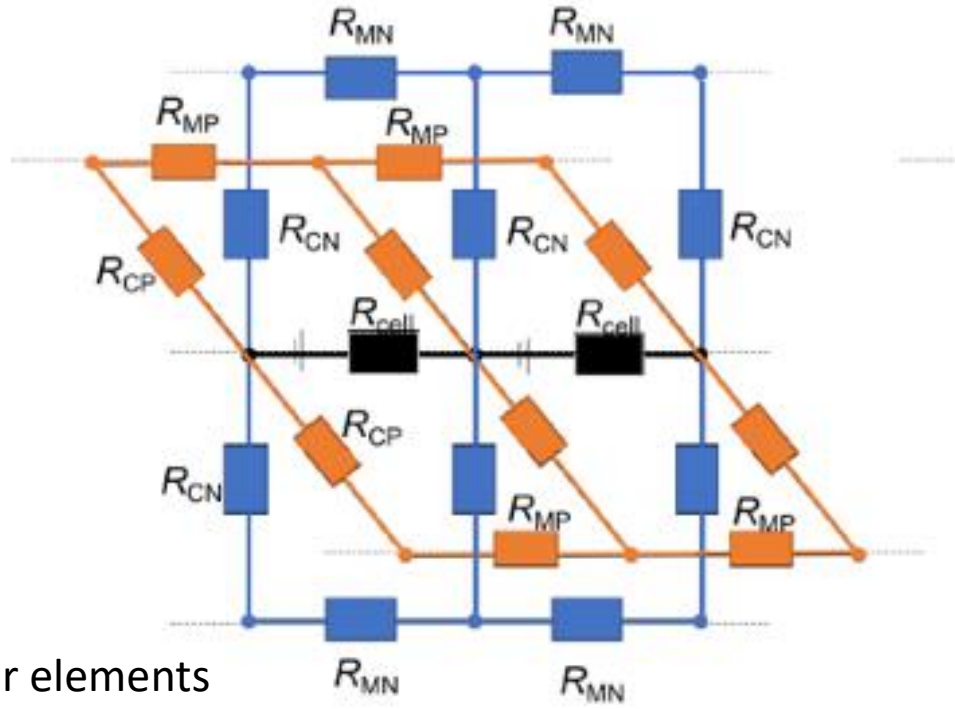
- Analytical model of shunt current losses and pressure losses
  - Optimization of sizes of channels and manifolds, flow rate
  - Optimization of size of active area
- CFD model
  - Optimization of preliminarily optimized design from analytical model

Analytical model - shunt current losses

- Shunt currents
  - Symmetrical equivalent circuit model
  - Solution of Kirchhoff's laws

$$\sum_{k=1}^{n} I_k = 0$$

$$\sum_{k=1}^{n} U_k = 0$$



- Assumptions
  - The surfaces of the electrolyte distribution system are non-conducting
  - The electrolyte flow paths are conductive and are represented by resistor elements
  - Each single cell is represented as an ideal voltage source in series with a resistor
  - The electrolyte in a single cell is assumed to have a uniform potential distribution

Analytical model - pressure losses

- Manifolds and guide channels

Bernoulli equation $$\Delta p = (\lambda \frac{l}{d_{\mathrm{eq}}} + \xi) \frac{\rho v^2}{2}$$

Re < 2300 $$\lambda = \frac{64}{Re}$$

Re > 2300 $$\lambda = \frac{0.25}{\left\{ \log \left[\left(\frac{6.81}{Re} \right)^{0.9} + \frac{\frac{\varepsilon}{d_{\mathrm{eq}}}}{3.7} \right] \right\}^2}$$

- Felt electrode

Darcy's law $$\Delta p = \frac{\mu \, l \, Q}{\kappa \, A}$$

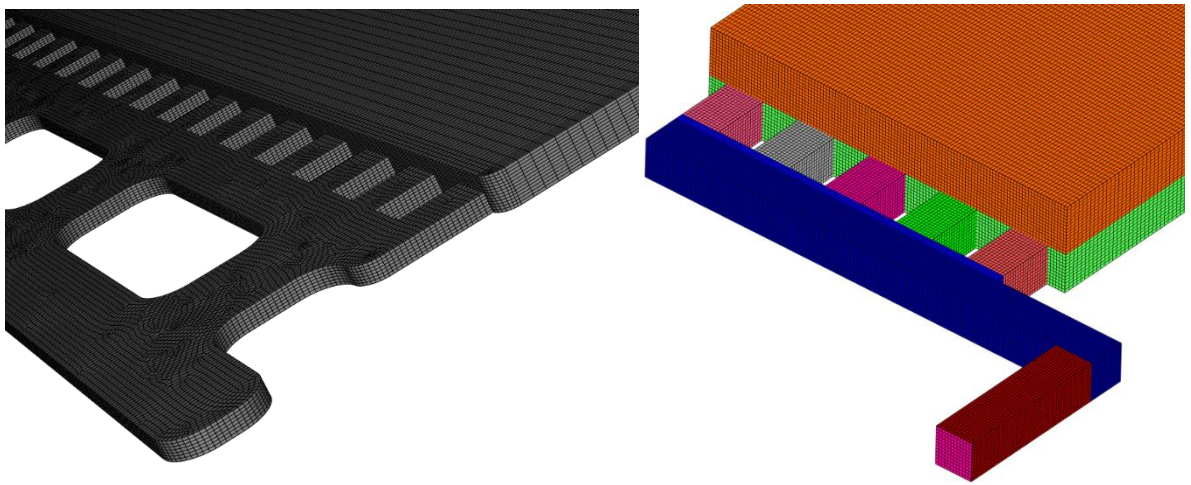
- Δp – pressure losses
- λ – friction loss coefficient
- l – length of the channel (electrode)
- d_{eq} – equivalent diameter of the channel
- ξ – local resistence coefficient
- ρ - density
- v - velocity
- Re – Reynolds number
- ε – roughness
- μ – viscosity
- Q – flow rate
- κ – permeability
- A – cross-sectional area of the felt

CFD model

- **Manifold and guide channels**

  Navier Stokes equations for laminar isothermal flow

  Optimize hexahedrons meshes



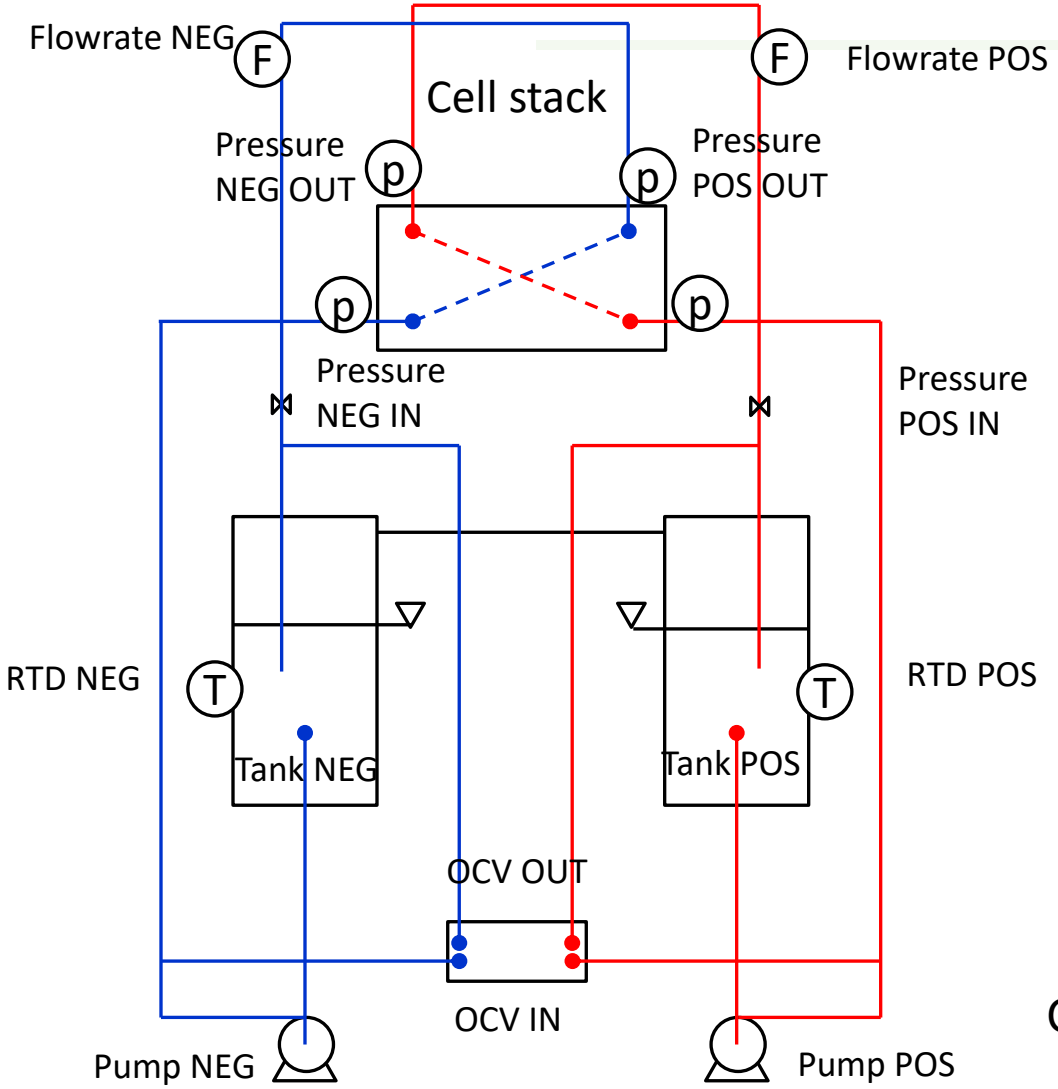
- **Felt electrode**

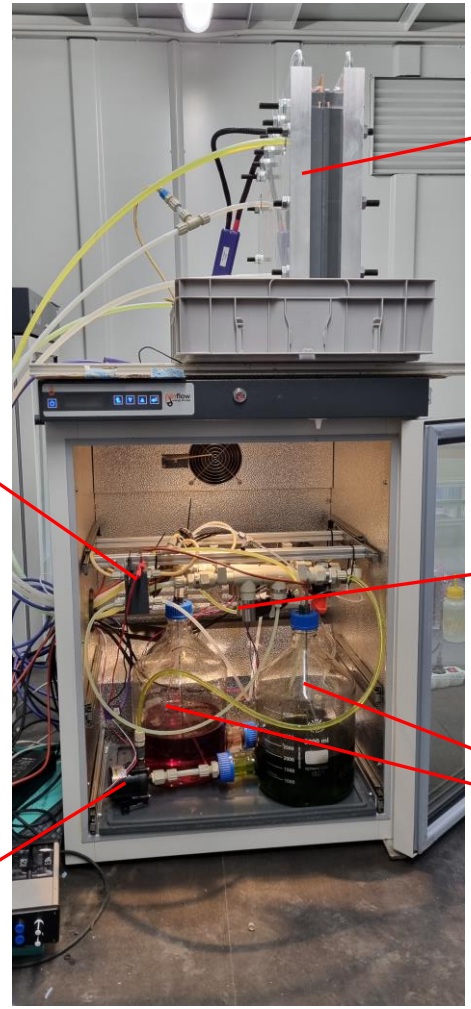
  Substituted by a porous zone with corresponding parameters

  Darcy's law

$$\Delta p = \frac{\mu l Q}{\kappa A}$$

Validation of models – experimental measurements





Battery cell

OCV cell

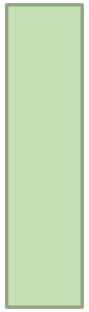
Pressure sensors

Reservoirs for electrolyte

Centrifugal pump

Cells

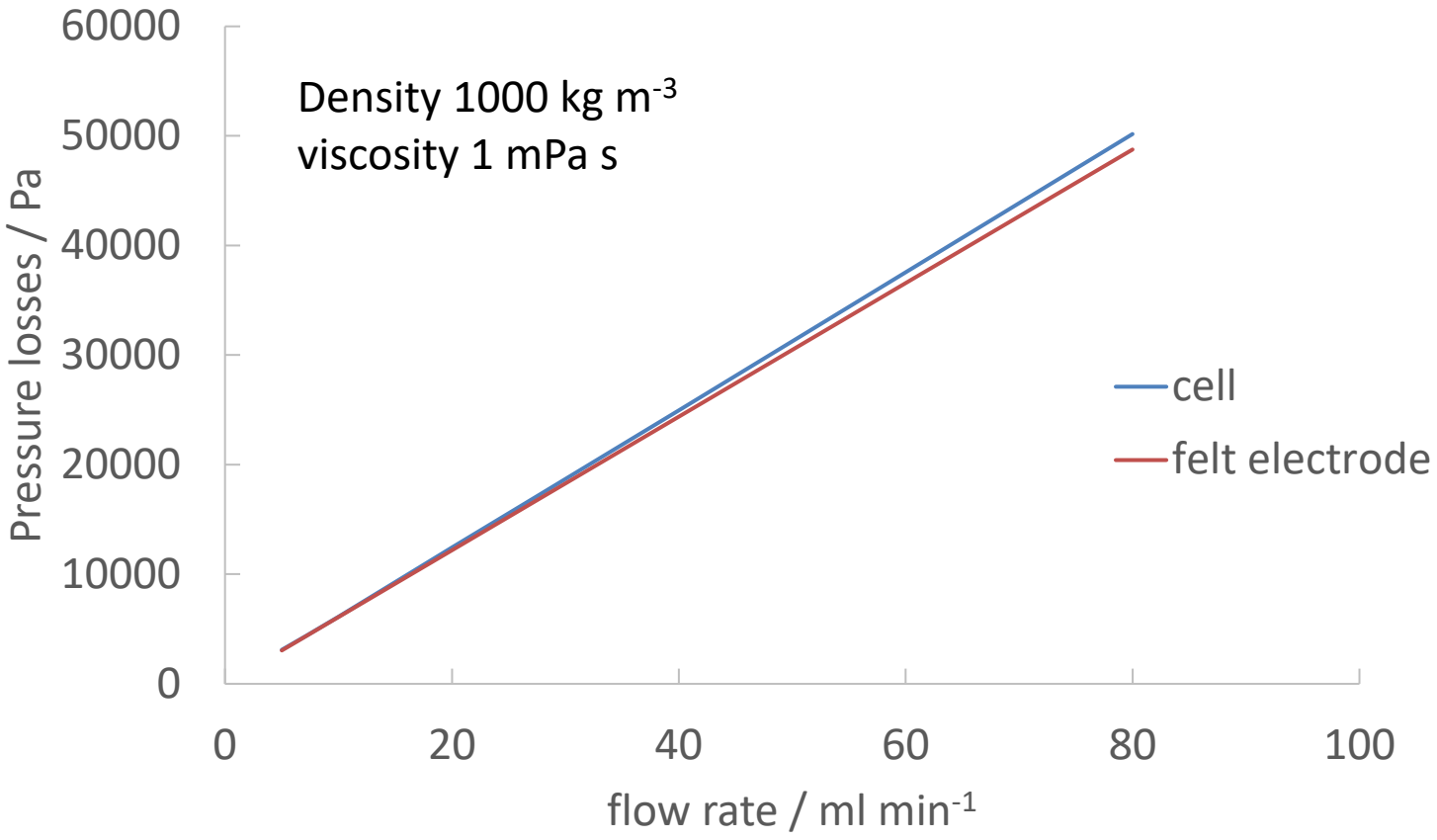
Cell A
16 cm^2

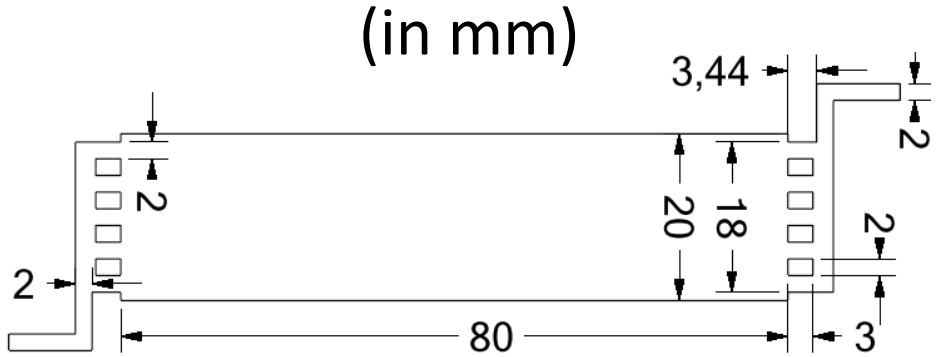


Cell B
364.5 cm^2

Cell C
608 cm^2

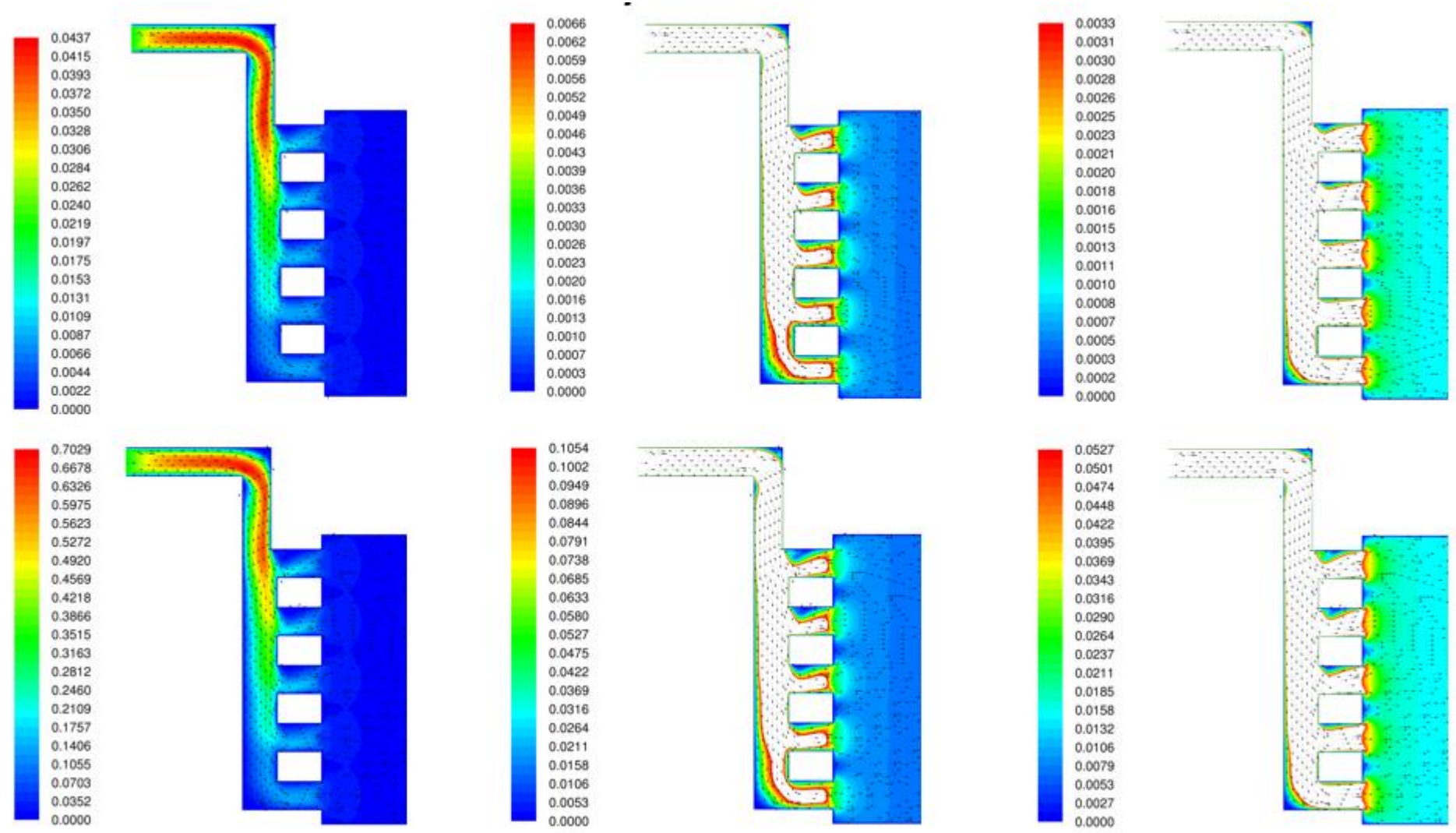
Cell A – 2 cm x 8 cm





- Majority of pressure losses in the felt electrode

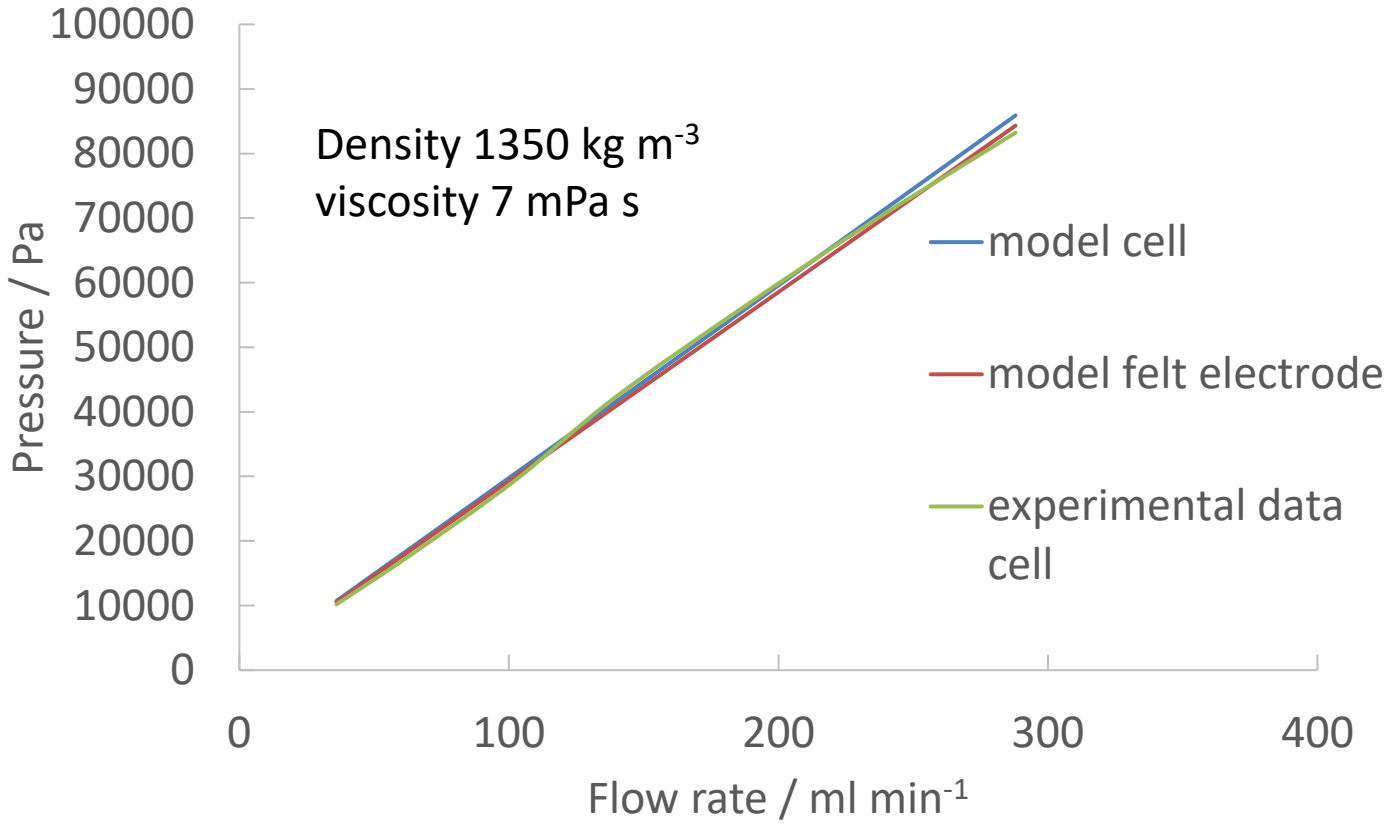
Cell A– flow distribution

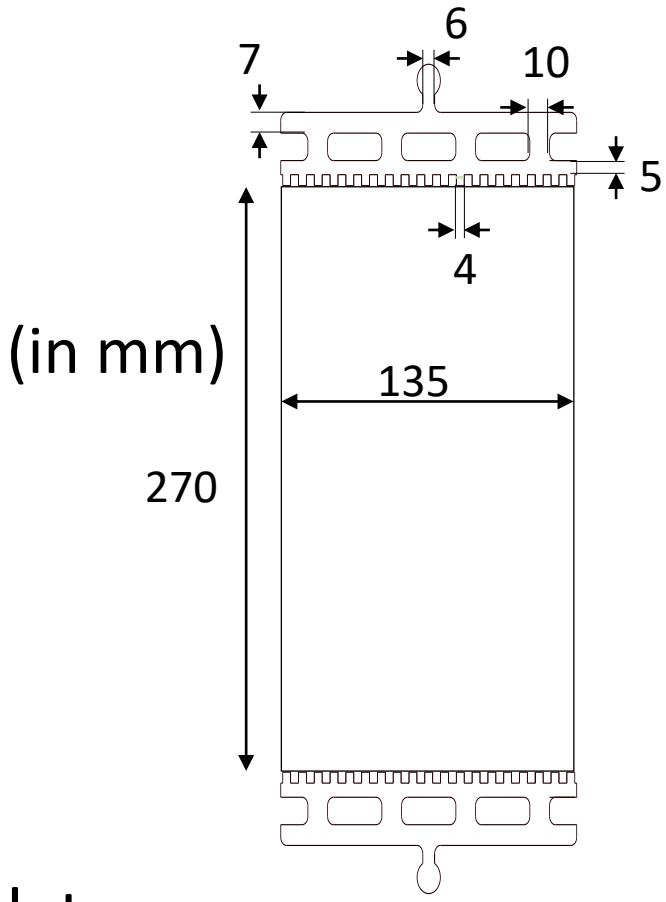


Flow rate
5 ml min^{-1};
density
1 kg l^{-1};
viscosity
1 mPa s

Flow rate
80 m l min^{-1};
density
1.3 kg l^{-1};
viscosity
12 mPa s

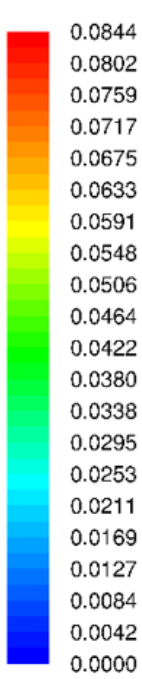
Cell B - 13.5 x 27 cm



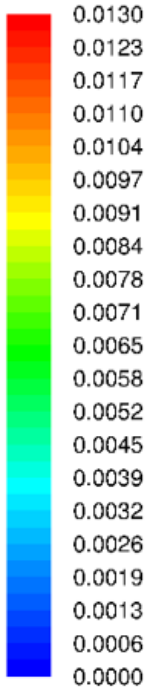


- Good agreement between models and experimental data

Cell B – flow distribution



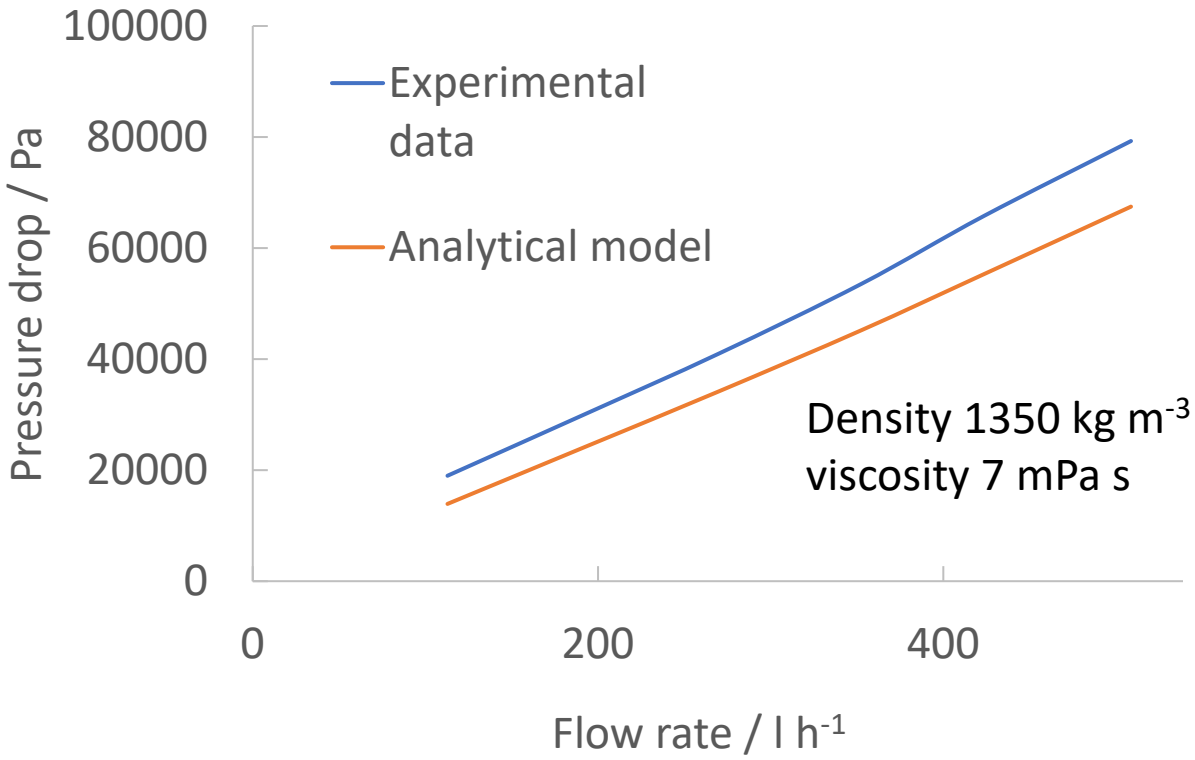
m s^{-1}

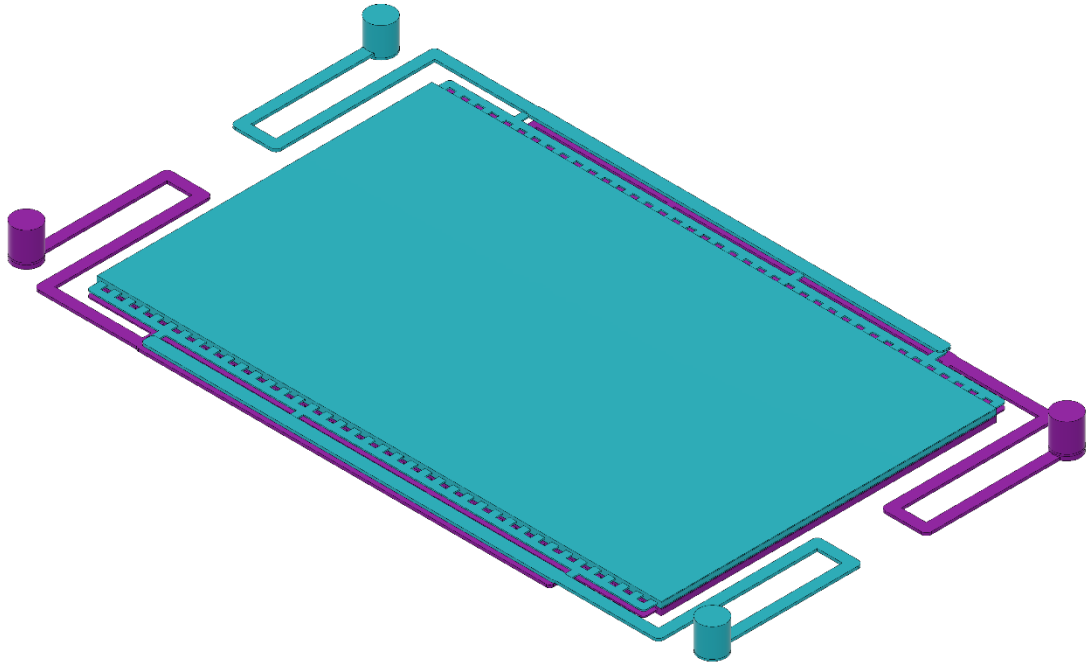


m s^{-1}

Flow rate 37 ml / min; density 1.35 kg/l; viscosity 7 mPa s

Cell C - 32 cm x 19 cm

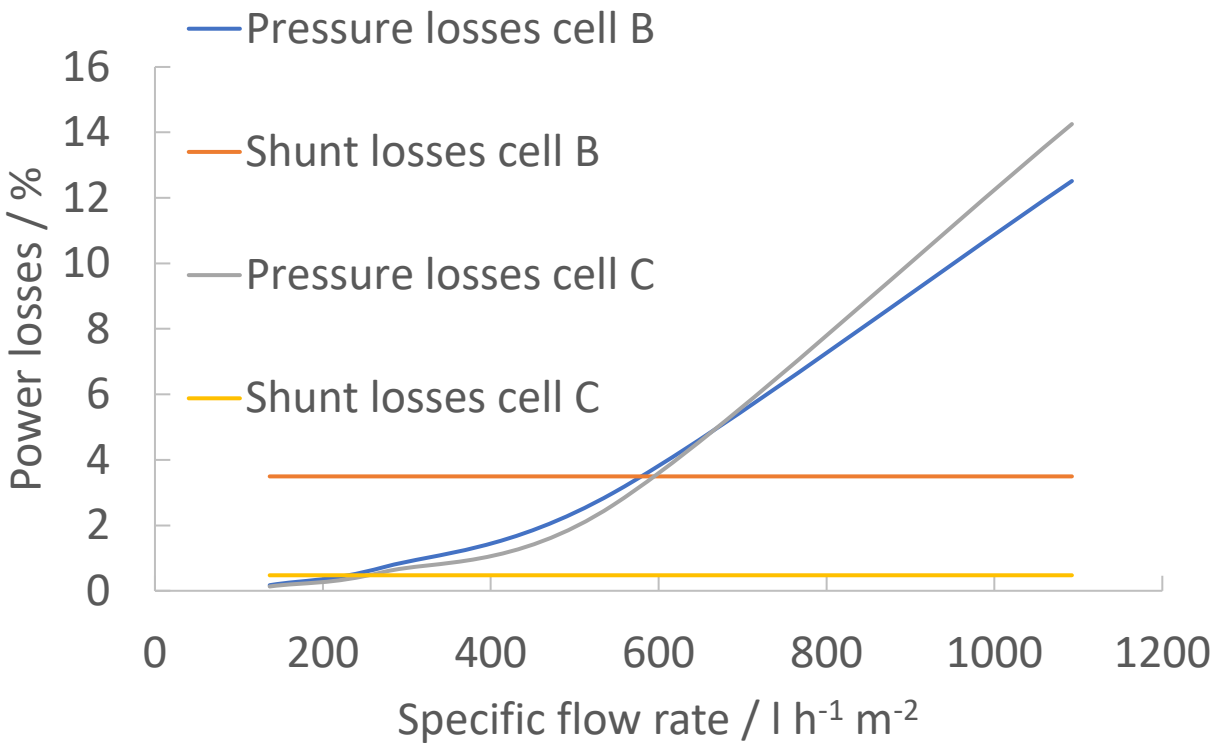




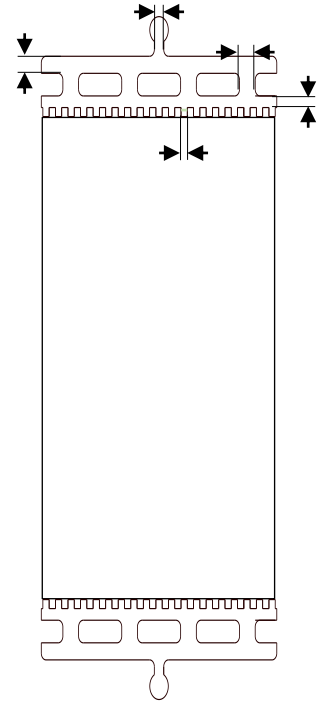
- Experimental data approximately 20 % higher
  - Inhomogeneity of felt material
  - Bad estimation of local resistance coefficients

Results from CFD model

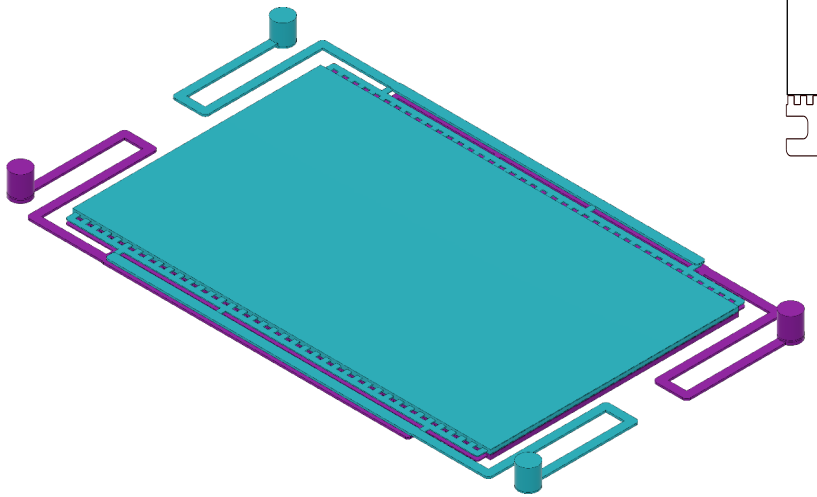
Comparison of cell B and C (40 cell stacks)



Cell B



Cell C



Electroytes used in Higreew project

Conclusions

- Analytical model of shunt current losses and pressure losses and CFD model were developed
- Analytical model – determination of basic parameters of the stack
- CFD model – optimization of preliminarily optimized geometry from analytical model
- Preliminarily optimized cell geometry shows much lower losses than non-optimized
- Optimization for ORFB is even more crucial than for VRFB due to significantly different properties of the electrolytes

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Thank you!

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

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