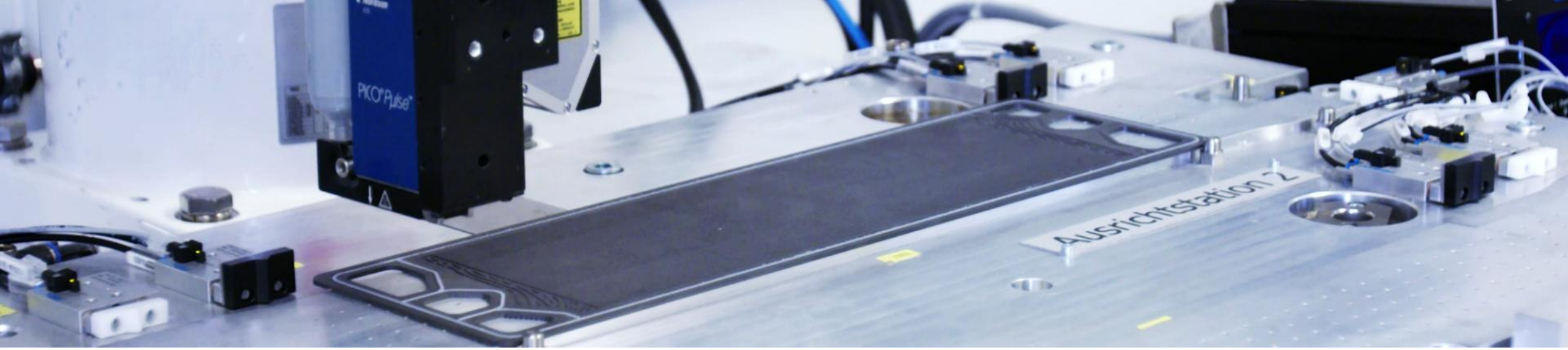
Zentrum für Sonnenenergie- und Wasserstoff-
Forschung Baden-Württemberg

HyFaB – Overall Concept and Generic Stack

16.06.2023 Introduction HyFaB

Frank Häußler, Dr. Joachim Scholta



HyFaB
Forschungsfabrik für H_2 und Brennstoffzellen

HYFAB: OVERALL CONCEPT

Fraunhofer ISE VDMA ZSW

HyFaB Project: "In a Nutshell"

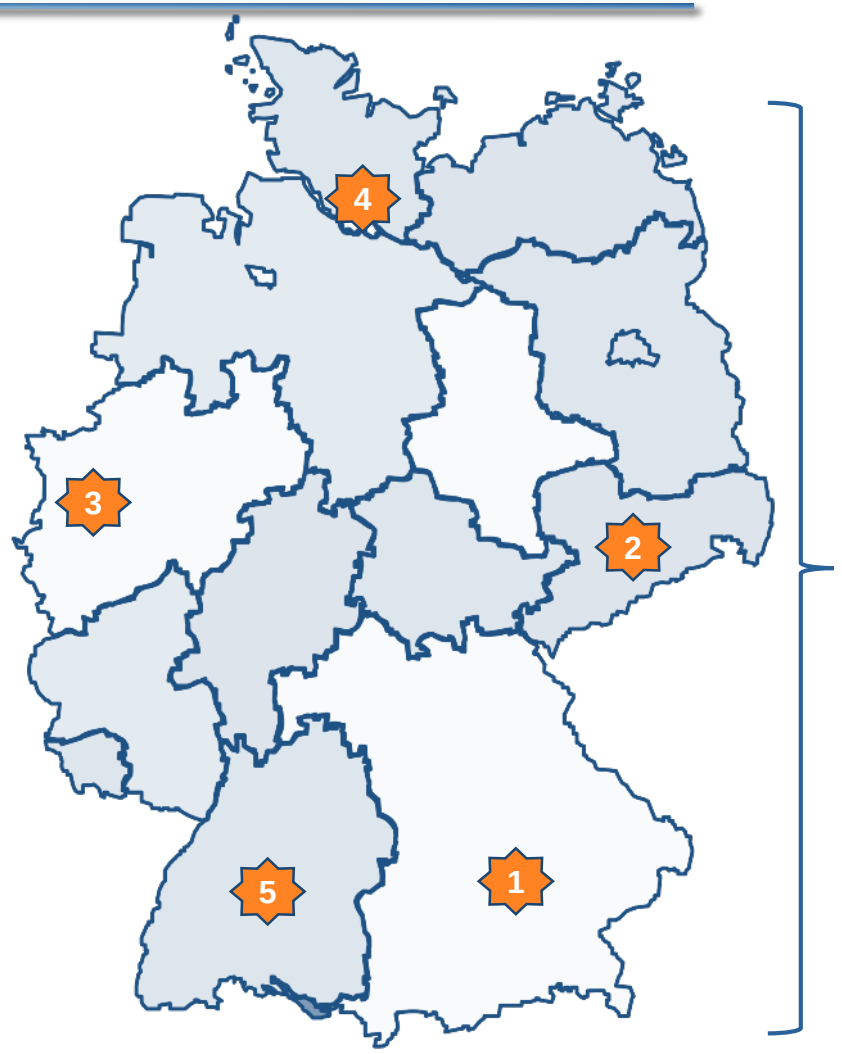
- Joint project of ZSW, Fraunhofer ISE and VDMA with financial support from State of Baden-Württemberg and Federal Ministries (WM and UM Baden-Württemberg and BMDV)
- Supporting the fuel cell industry in Germany in the transition from manual assembly to industrialization
- Main focus: PEM fuel cell stack and its components, assembly, end-of-line testing and commissioning
- Entry platform for newcomers, especially for small and medium sized enterprises
- Evaluation of quality procedures
- Building up industry know-how
- Education and training for specialists - information to the public
- Provision of a manufacturer-independent "generic stack" as uniform hardware for partners, co-developers …

„Do not reinvent the wheel – get it rolling!"

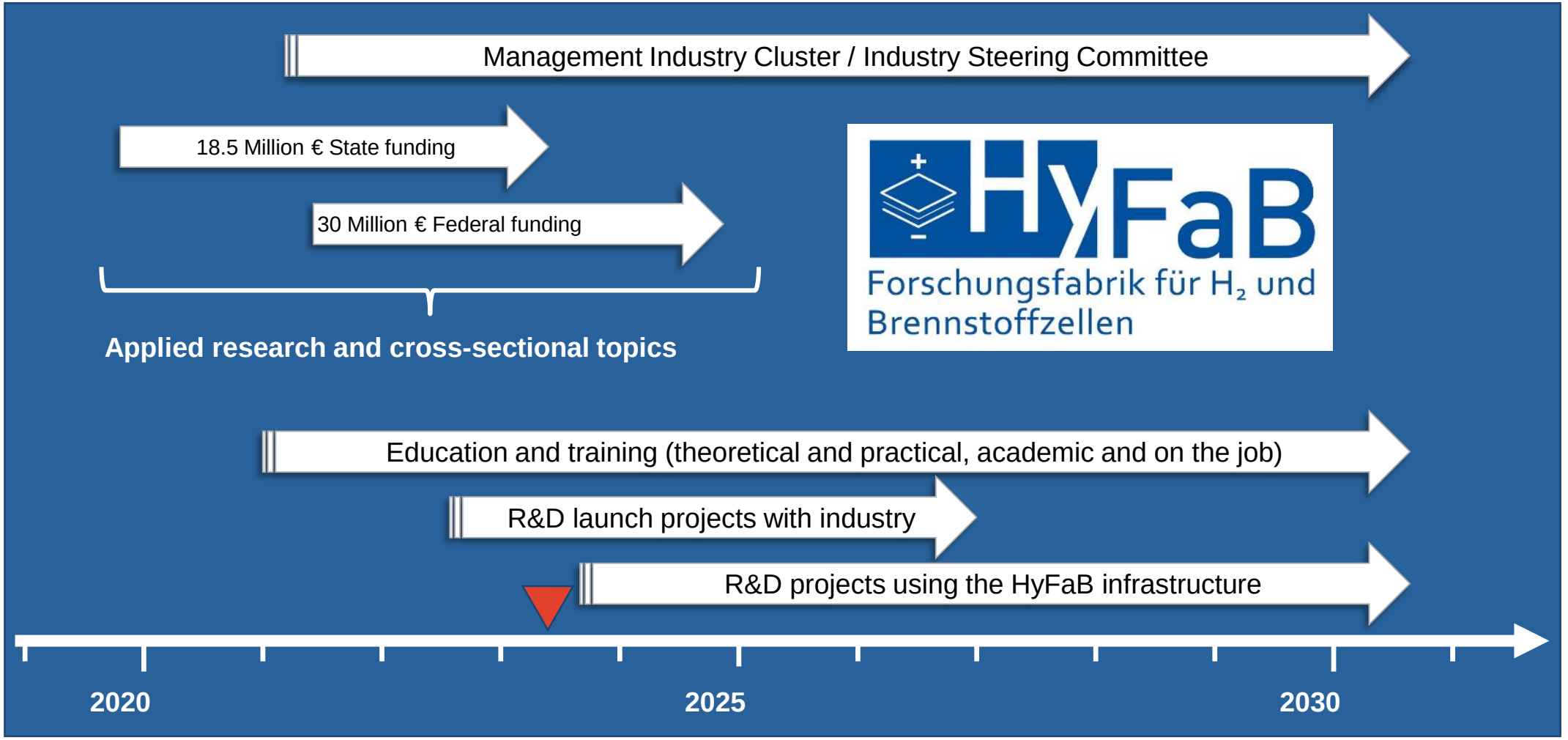
HyFaB seen as Part of the Hydrogen Centers at the Federal Level

5 Technology & innovation centers - 350 million euros by 2024

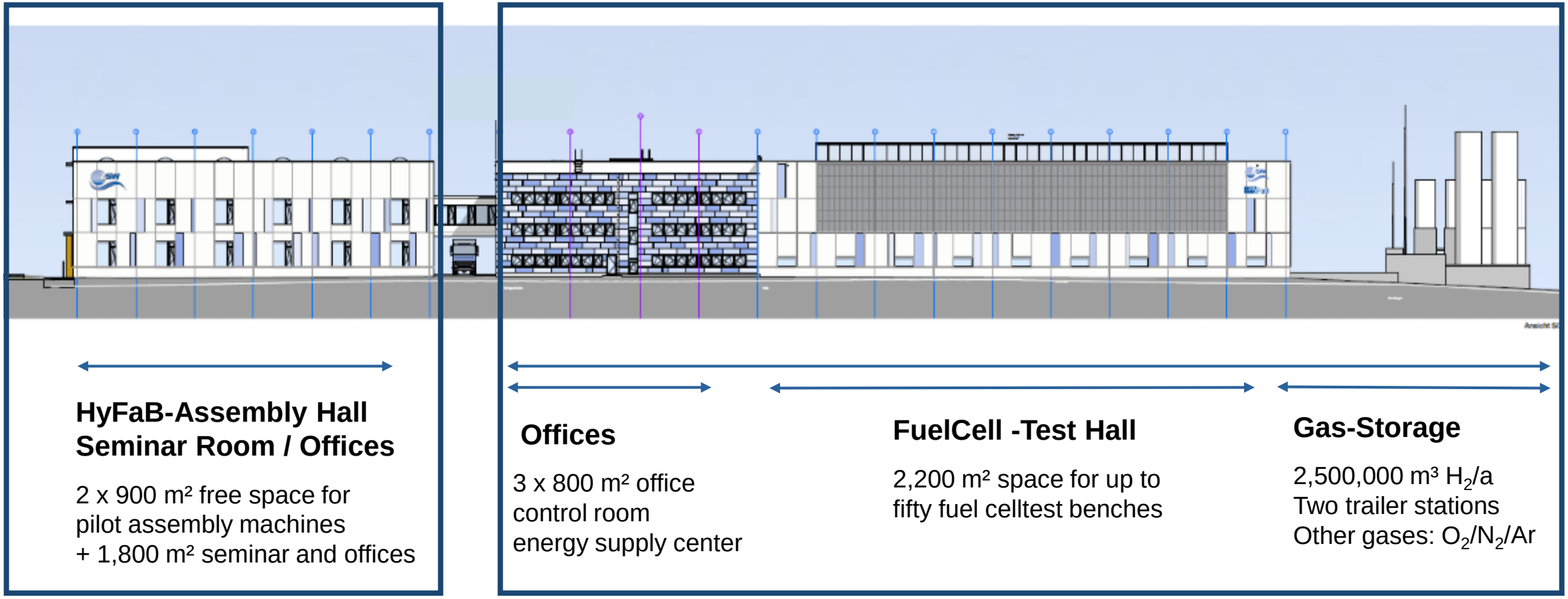
1. **Hydrogen Technology Application Center (WTAZ) in Pfeffenhausen near Landshut:**
   - Technology transfer & applied R&D. Focus on liquid hydrogen;
   - Funding of 70 + x million euros
2. **Hydrogen and Mobility Innovation Center (HIC) in Chemnitz, Germany:**
   - Fuel cells for vehicle applications;
   - Funding of 70 + x million euros
3. **Technology and Innovation Center Hydrogen Technologies (TrH2) in Duisburg:**
   - Tests of FC propulsion systems for road, rail, water & air transport, education & training (startup & SMEs);
   - Funding of 70 + x million euros
4. **Hydrogen Innovation and Technology Center (ITZ) Northern Germany Bremen/Hamburg/Stade:**
   - Hydrogen technology for aviation & shipping;
   - Funding of 70 + x million euros
5. **HyFaB in Ulm and Freiburg:**
   - Industrialization of fuel cell stacks and their components;
   - Funding of up to 80 million euros



HyFaB Project: Overall Timeline at a Glance



HyFaB-Building Complex @ ZSW – to be finished 08/2023



HyFaB-Assembly Hall
Seminar Room / Offices

2 x 900 m² free space for
pilot assembly machines
+ 1,800 m² seminar and offices

Offices

3 x 800 m² office
control room
energy supply center

FuelCell -Test Hall

2,200 m² space for up to
fifty fuel celltest benches

Gas-Storage

2,500,000 m³ H_2/a
Two trailer stations
Other gases: O_2/N_2/Ar

Stage #2: 02/2022 – 08/2023

Stage #1: 02/2021 - 05/2022

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Stage #1: 02/2021 - 05/2022

Building complex HyFaB, May 5th 2023

HyFaB - Fuel Cell Test-Hall @ ZSW

- Largest public fuel cell test facility in Europe
- 50 test benches by end of 2023 from single kW size to 250 kW

HyFaB: First installed Fuel Cells Test Benches - October 2022

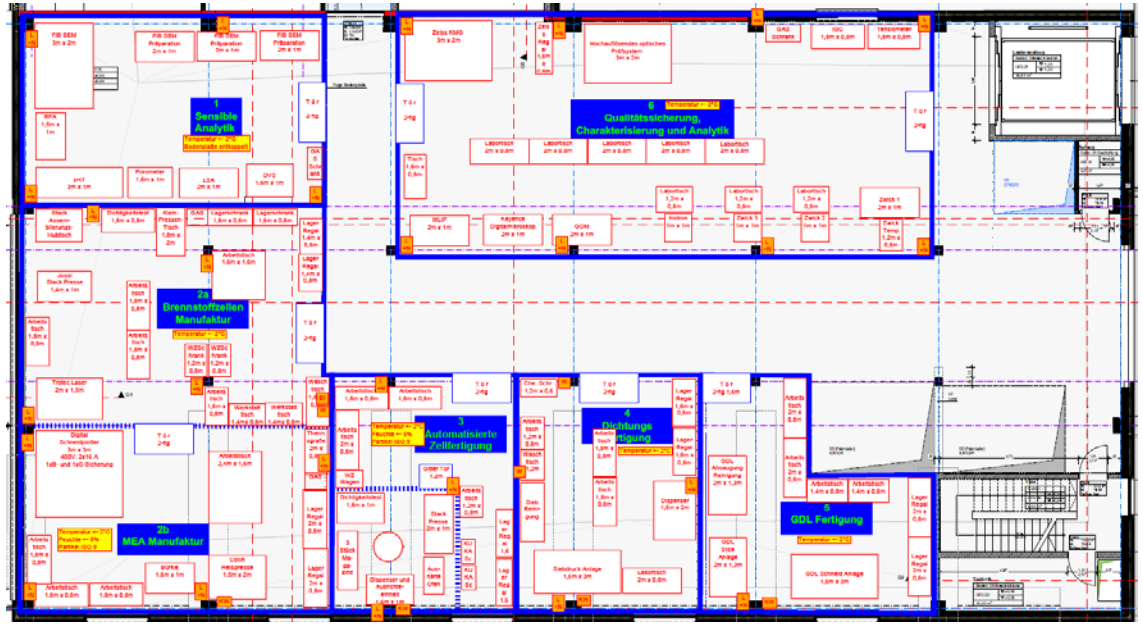
HyFaB Assembly-Hall @ ZSW

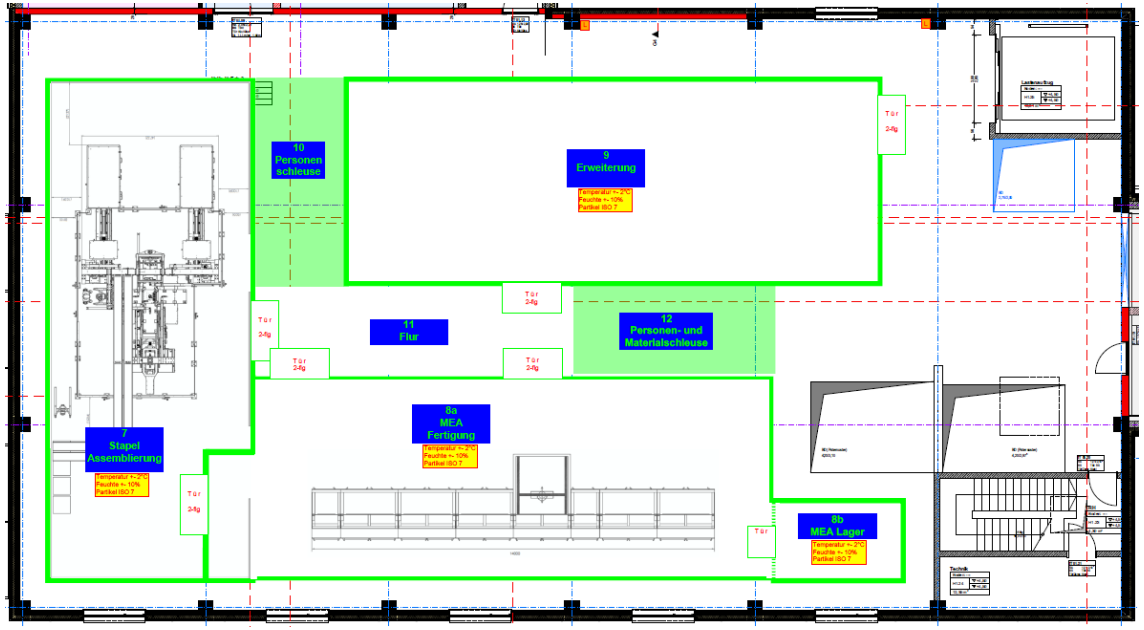
Ground floor: Technical Center Hall

- Room in room concept executed as air-conditioned clean rooms
- Manufacture, analytics, QA and characterization

Upper floor: Production Hall

- Room in room concept (clean rooms up to class ISO 7)
- Mühlbauer: Stack Assembly Line
- Optima: MEA Converting Line



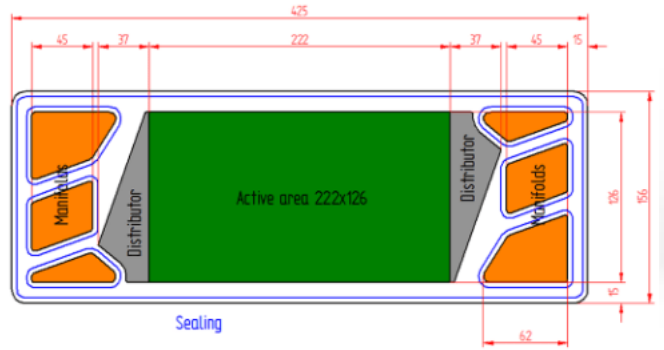


HYFAB – GENERIC STACK

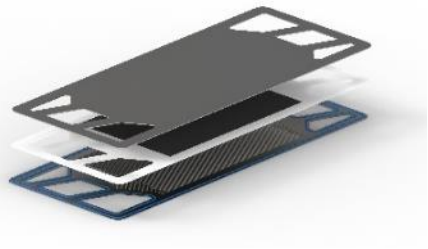
HyFaB @ ZSW: Generic Stack - an open & modular stack design

State of the art sample parts for the fuel cell industry:

- Preliminary work in FVV project "generic stack“ with consensus on high-level specifications
- Flow simulations done and available to 3rd parties
- Power density as for automotive application up to 150 kW
- Free of third party rights (targeted)
- EKPO announced as industrial partner for series production of metallic bipolar plates - product available by order
- First demand for sample parts in industry secured
- Bipolar plates in graphitic design to be initiated

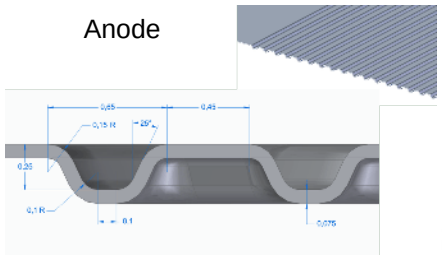


BPP-Design

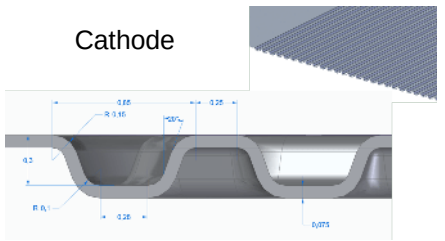


Single cell

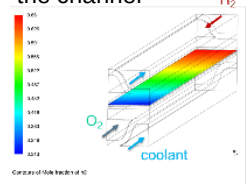
Anode

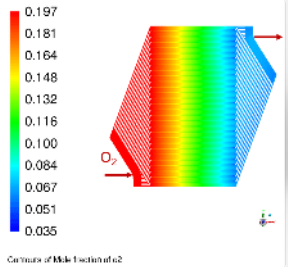


Cathode



Hydrogen content in the channel





Oxygen content on the active surface

Rendering: 300 cells stack

Generic Stack – BPP simulation

Objectives

Designing of metallic bipolar plates (BPP) using Computational Fluid Dynamics (CFD*). The BPP's are designed for a generic stack used as an open base development platform within the HyFaB-BW project.

Single cell / BPP flow field simulations

Adapting:

- Distributer areas and channel cross sections (channel flow distribution)
- Channel-land ratio (diffusion length for reactants)

to optimise:

- Reactant distribution at catalyst layers
- Temperature distribution
- Auxiliary power ($\Delta p_{BPP,ff}$)
- Alignment of design requirements and manufacturability

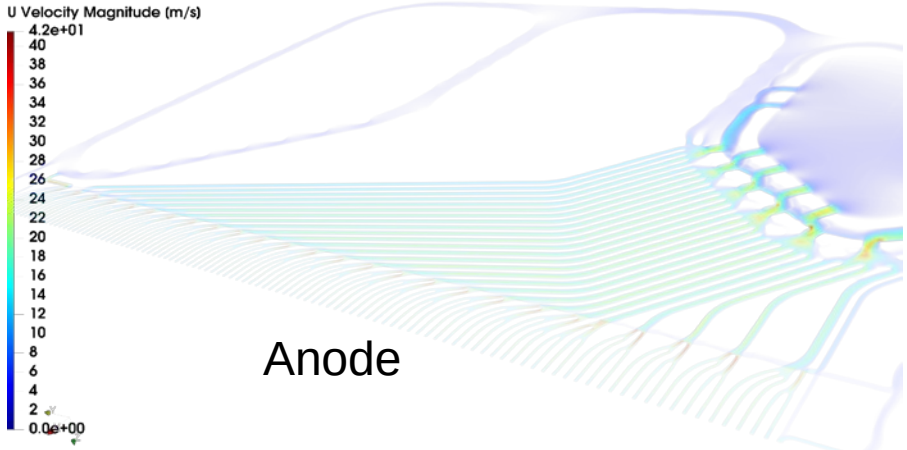
*OpenFOAM (open source (GNU)) and ANSYS® FLUENT® (commercial) were used.

Boundary conditions

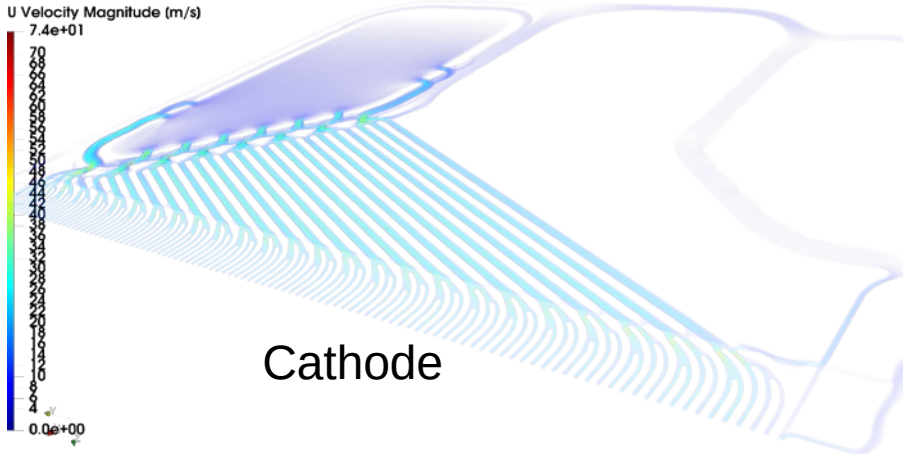
Boundary Conditions		Anode	Cathode	Coolant
Pressure (bara)	Inlet	2.42	2.25	-
	Outlet	2.20	2.00	0.00
Temperature (°C)	Inlet	95.0	83.0	83.0
	Outlet	83.0	95.0	95.0
Dew point temperature (°C)	Inlet	71.9	70.7	-
Relativ Humidity	Inlet	44%	68%	-
@ $T_{in-/out}$	Outlet	105%	77%	-
mole fraction H2 / O2 dry	Inlet	0.70	0.21	-
mole fraction N2 dry	Inlet	0.30	0.79	-
Utilisation		67%	56%	
Lambda		1.50	1.80	

Cell acitive area (cm²)	280	(theoretical) η_el	39%
Current I (A)	700	(theoretical) P_th (W)	630.4
Current density i (A/cm²)	2.50	Coolant mass flow (kg/s)	1.25E-02
Cell potential U (V)	0.580	Stack potential U (V)	1
Cell power P_el (W)	406.3	Stack power P_el (kW)	0.4

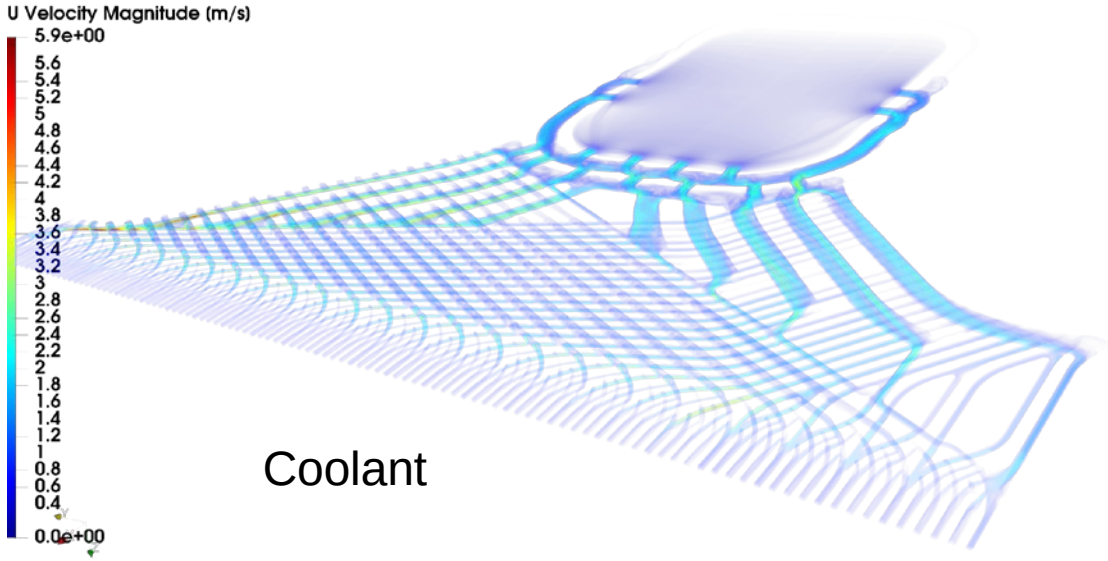
Generic Stack – BPP simulation volume renderings



Volume render of velocity magnitude (m/s) at anode inlet distributor

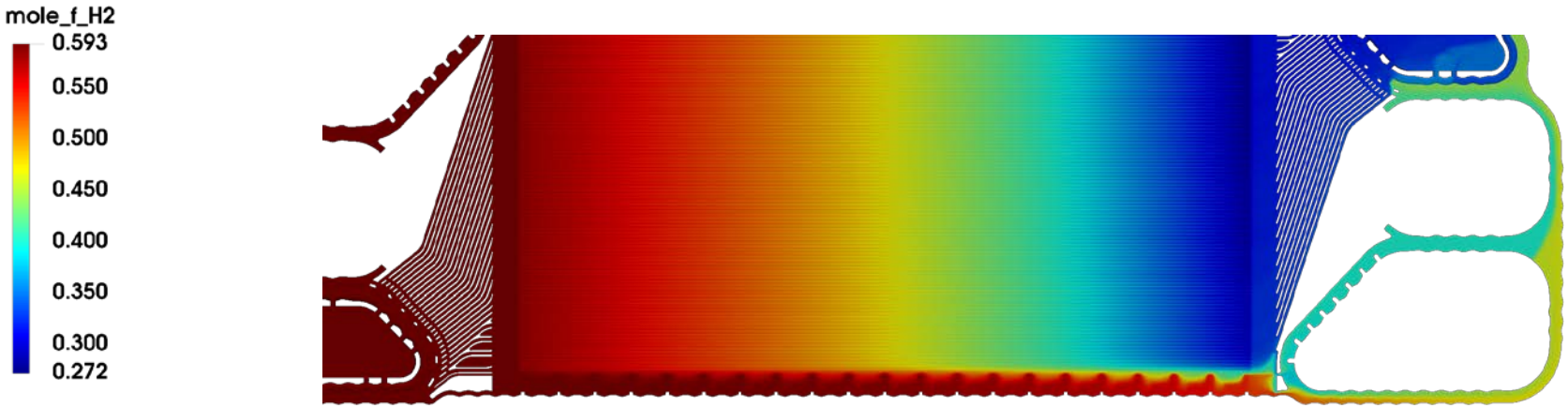


Volume render of velocity magnitude (m/s) at cathode inlet distributor



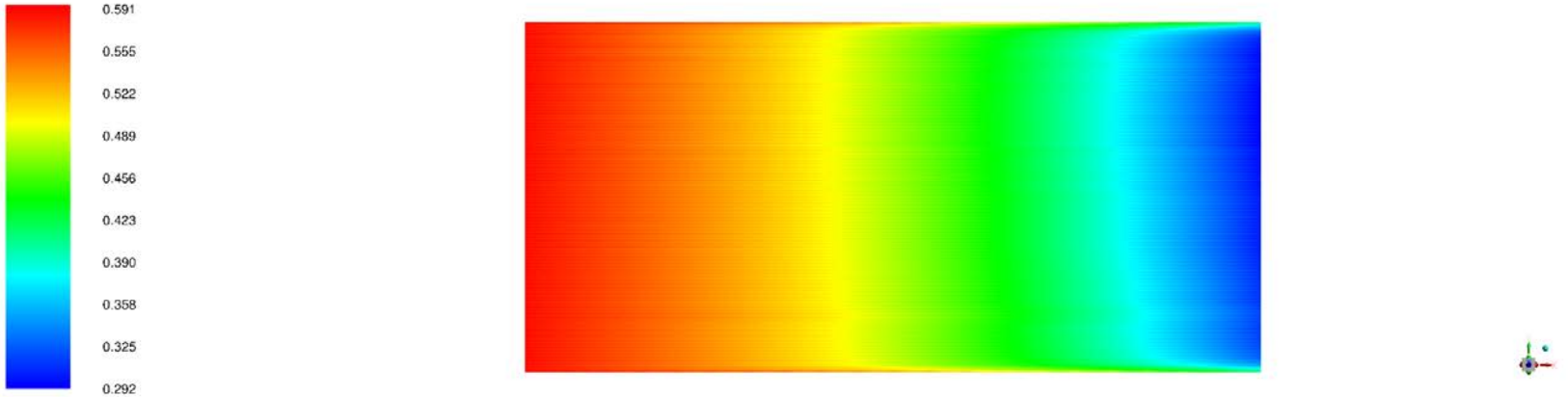
Volume render of velocity magnitude (m/s) at coolant inlet distributor

Generic Stack – BPP simulation reactant distribution



Intermediate Version:
H_2 minimum reactant mole fraction 0,272

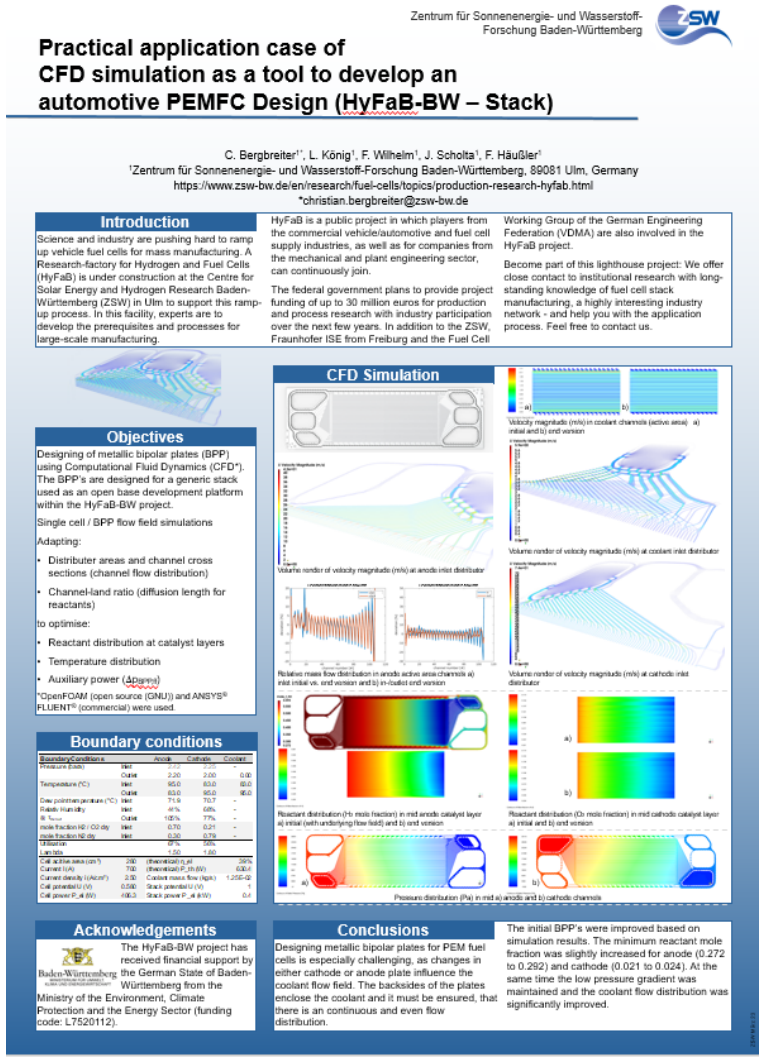
Intermediate Version: reactant distribution (H_2 mole fraction) in mid anode catalyst layer with underlying flow field



End Version:
H_2 minimum reactant mole fraction 0,292

End version: Reactant distribution (H_2 mole fraction) in mid anode catalyst layer

Generic Stack – BPP simulation poster for „ModVal 2023“



Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg

Practical application case of CFD simulation as a tool to develop an automotive PEMFC Design (HyFaB-BW – Stack)

C. Bergbreiter[1*], L. König[1], F. Wilhelm[1], J. Scholta[1], F. Häußler[1]
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https://www.zsw-bw.de/en/research/fuel-cells/topics/production-research-hyfab.html
*christian.bergbreiter@zsw-bw.de

Introduction

Science and industry are pushing hard to ramp up vehicle fuel cells for mass manufacturing. A Research-factory for Hydrogen and Fuel Cells (HyFaB) is under construction at the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) in Ulm to support this ramp-up process. In this facility, experts are to develop the prerequisites and processes for large-scale manufacturing.

HyFaB is a public project in which players from the commercial vehicle/automotive and fuel cell supply industries, as well as for companies from the mechanical and plant engineering sector, can continuously join.

The federal government plans to provide project funding of up to 30 million euros for production and process research with industry participation over the next few years. In addition to the ZSW, Fraunhofer ISE from Freiburg and the Fuel Cell Working Group of the German Engineering Federation (VDMA) are also involved in the HyFaB project.

Become part of this lighthouse project: We offer close contact to institutional research with long-standing knowledge of fuel cell stack manufacturing, a highly interesting industry network - and help you with the application process. Feel free to contact us.

Objectives

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Single cell / BPP flow field simulations

Adapting:

- Distributer areas and channel cross sections (channel flow distribution)
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to optimise:

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- Temperature distribution
- Auxiliary power (Δp_{anode})

*OpenFOAM (open source (GNU)) and ANSYS® FLUENT® (commercial) were used.

CFD Simulation

Boundary conditions

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	Outlet	2.20	2.00	0.00
Temperature (°C)	Inlet	95.0	83.0	83.0
	Outlet	83.0	95.0	95.0
Dew point temperature (°C)	Inlet	71.9	70.7	-
Relativ Humidity	Inlet	97%	68%	-
Φ Tunnel	Outlet	105%	77%	-
mole fraction H2 / O2 dry	Inlet	0.70	0.21	-
mole fraction N2 dry	Inlet	0.30	0.79	-
Utilisation		97%	58%	
Lambda		1.50	1.60	
Cell active area (cm²)	250	(theoretical) η_{el}		59%
Current I (A)	700	(theoretical) P_th (W)		630.4
Current density i (A/cm²)	2.80	Coolant mass flow (kg/s)		1.25E-02
Cell potential U (V)	0.590	Stack potential U (V)		1
Cell power P_el (W)	406.0	Stack power P_el (kW)		0.4

Acknowledgements

The HyFaB-BW project has received financial support by the German State of Baden-Württemberg from the Ministry of the Environment, Climate Protection and the Energy Sector (funding code: L7520112).

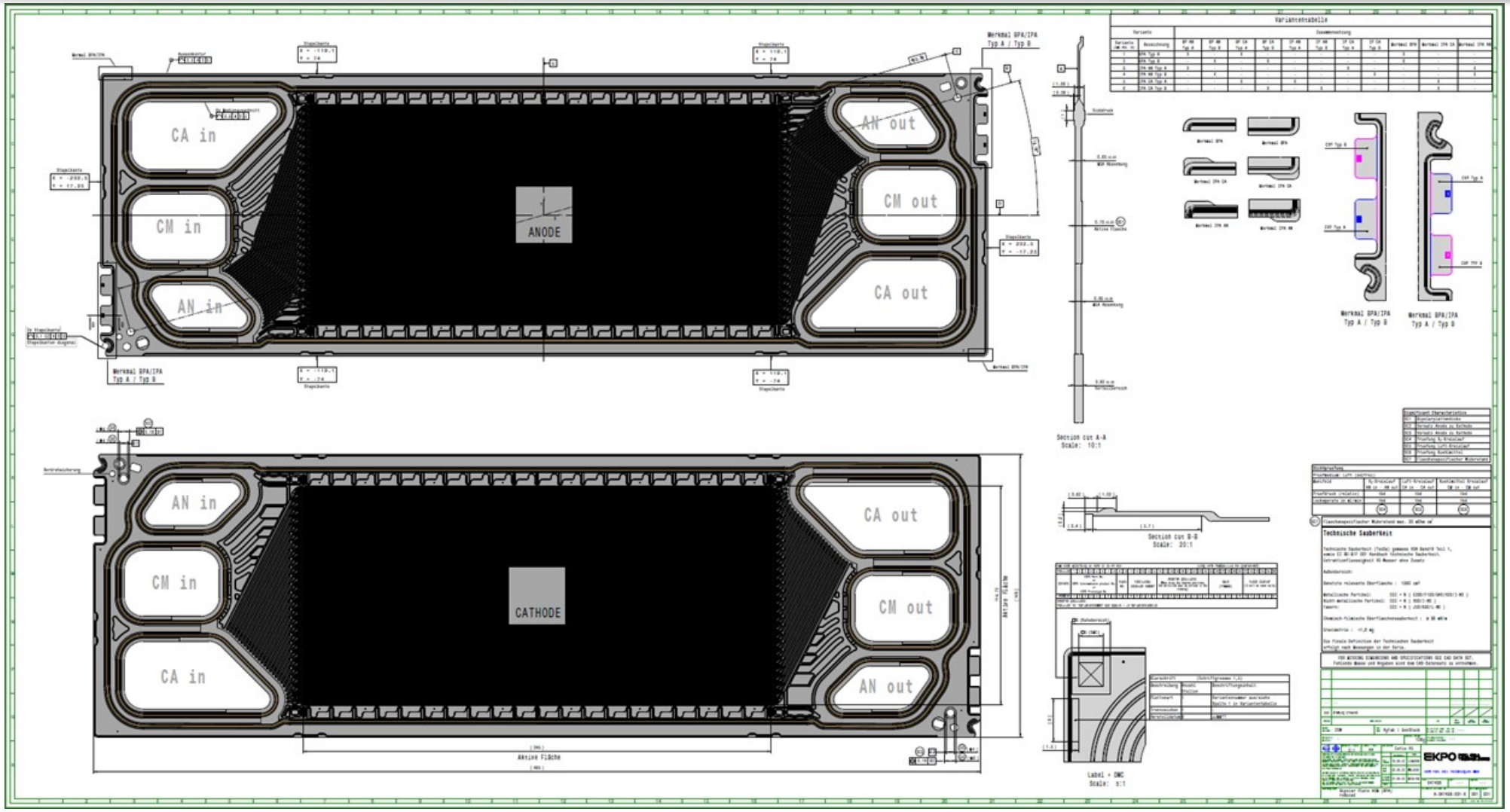
Conclusions

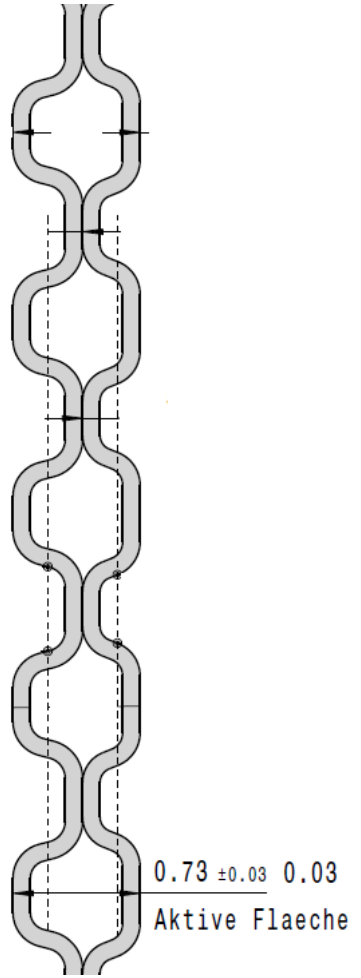
Designing metallic bipolar plates for PEM fuel cells is especially challenging, as changes in either cathode or anode plate influence the coolant flow field. The backsides of the plates enclose the coolant and it must be ensured, that there is an continuous and even flow distribution.

The initial BPP's were improved based on simulation results. The minimum reactant mole fraction was slightly increased for anode (0.272 to 0.292) and cathode (0.021 to 0.024). At the same time the low pressure gradient was maintained and the coolant flow distribution was significantly improved.

Generic Stack - BPP

Generic Stack BPP - Drawing





Generic Stack BPP – Different Types

24	25	26	27	28	29	30	31

Variantentabelle

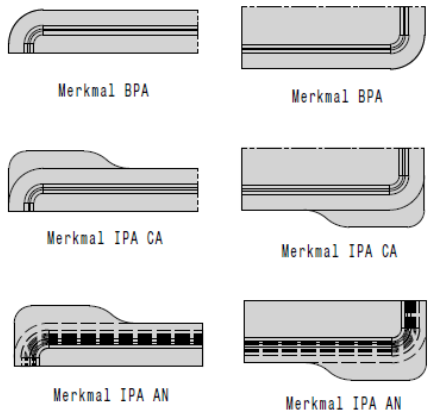
Variante		Zusammensetzung										
Variante (DMC Pos. 16)	Bezeichnung	BP AN Typ A	BP AN Typ B	BP CA Typ A	BP CA Typ B	IP AN Typ A	IP AN Typ B	IP CA Typ A	IP CA Typ B	Merkmal BPA	Merkmal IPA CA	Merkmal IPA AN
1	BPA Typ A	X	-	X	-	-	-	-	-	X	-	-
2	BPA Typ B	-	X	-	X	-	-	-	-	X	-	-
3	IPA AN Typ A	X	-	-	-	-	-	X	-	-	-	X
4	IPA AN Typ B	-	X	-	-	-	-	-	X	-	-	X
5	IPA CA Typ A	-	-	X	-	X	-	-	-	-	X	-
6	IPA CA Typ B	-	-	-	X	-	X	-	-	-	X	-

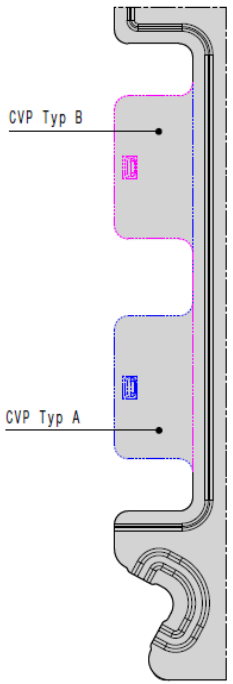
uck

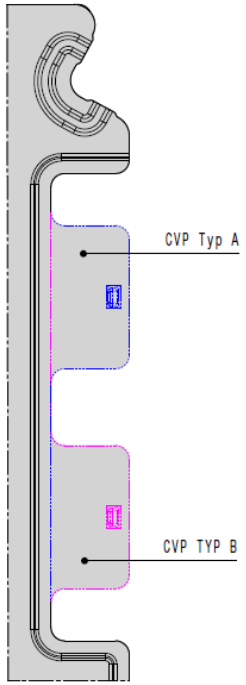
±0.03
Absenkung

0.03 (SC1)
Flaeche

).03







A B C D E F

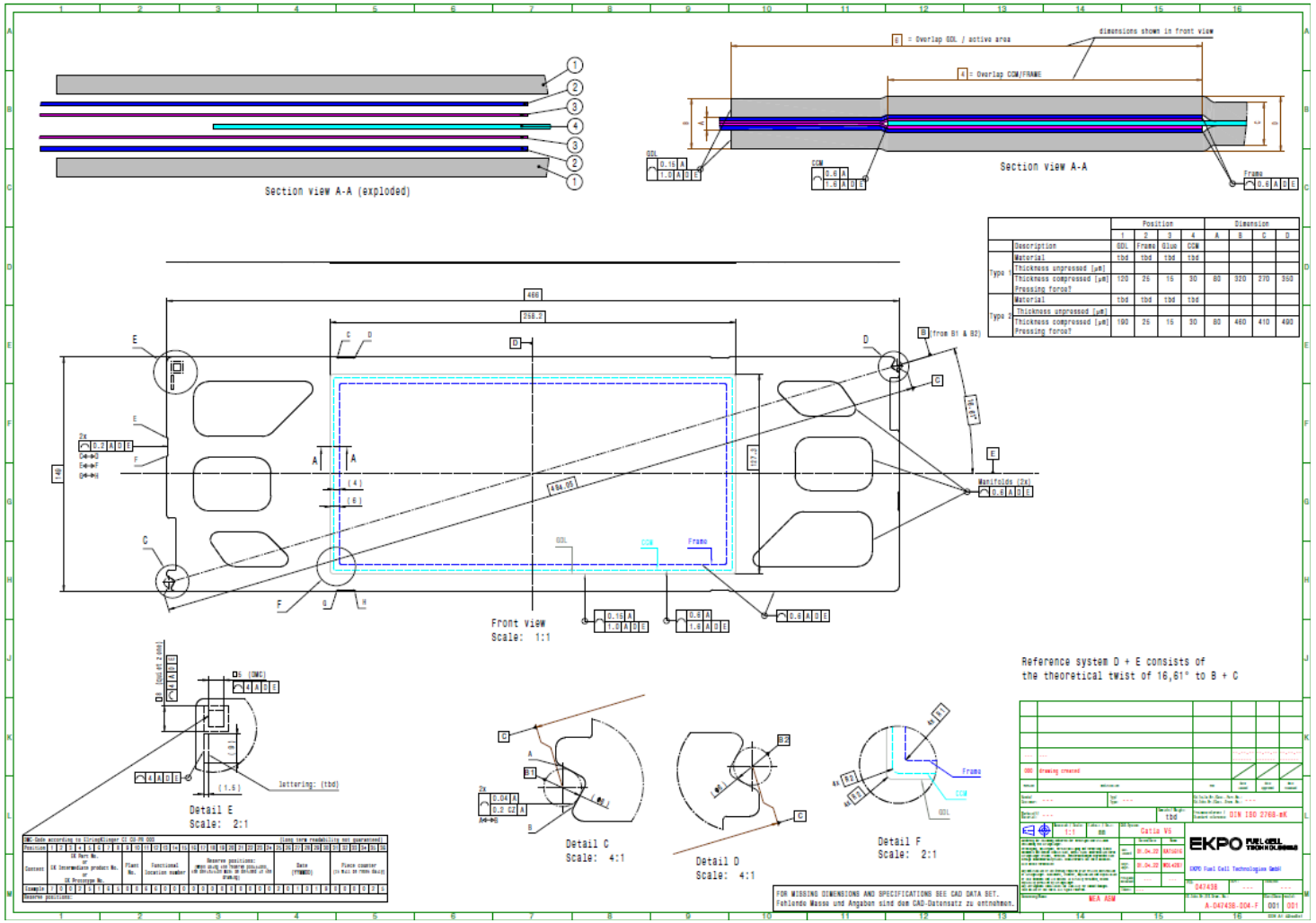
Generic Stack BPP – General Conditions

General remark

- **The BPPs developed and produced as part of the "HyFaB" project are not suitable for commercial use and will not be used by third parties in a commercially used intermediate or end product, as the products supplied by EKPO Fuel Cell Technologies GmbH and sold by ZSW are prototypes for research and development purposes.**

- EKPO sells and delivers exclusively to ZSW as a customer (not to third parties).
- ZSW orders the products taking into account the respective delivery lot size
- ZSW resells the products to third parties

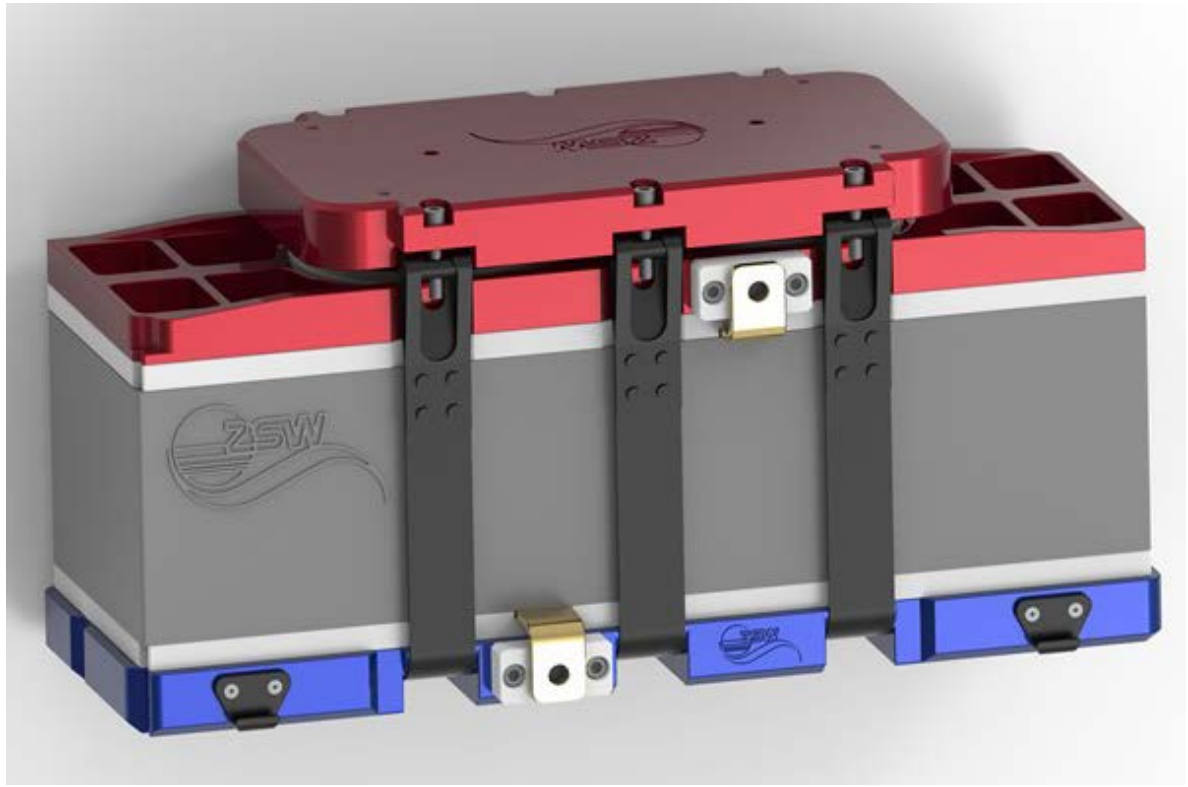
Generic Stack MEA – 7-layer Design



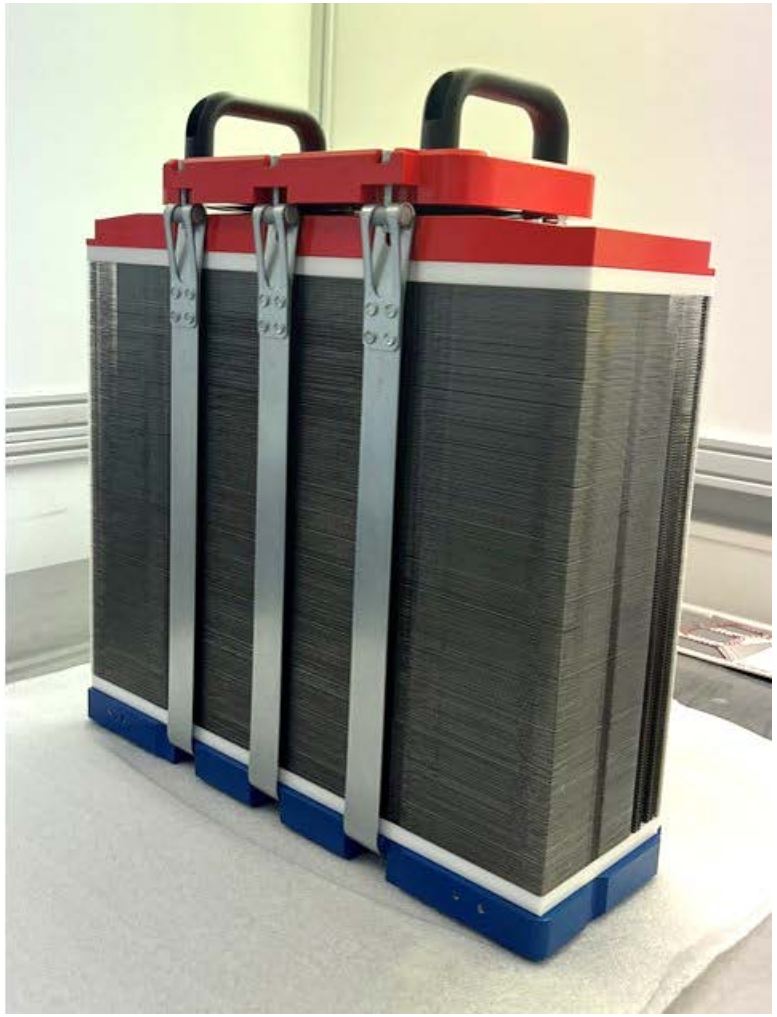
GDL thickness in compressed state:

- Min. 120µm
- Max. 190µm

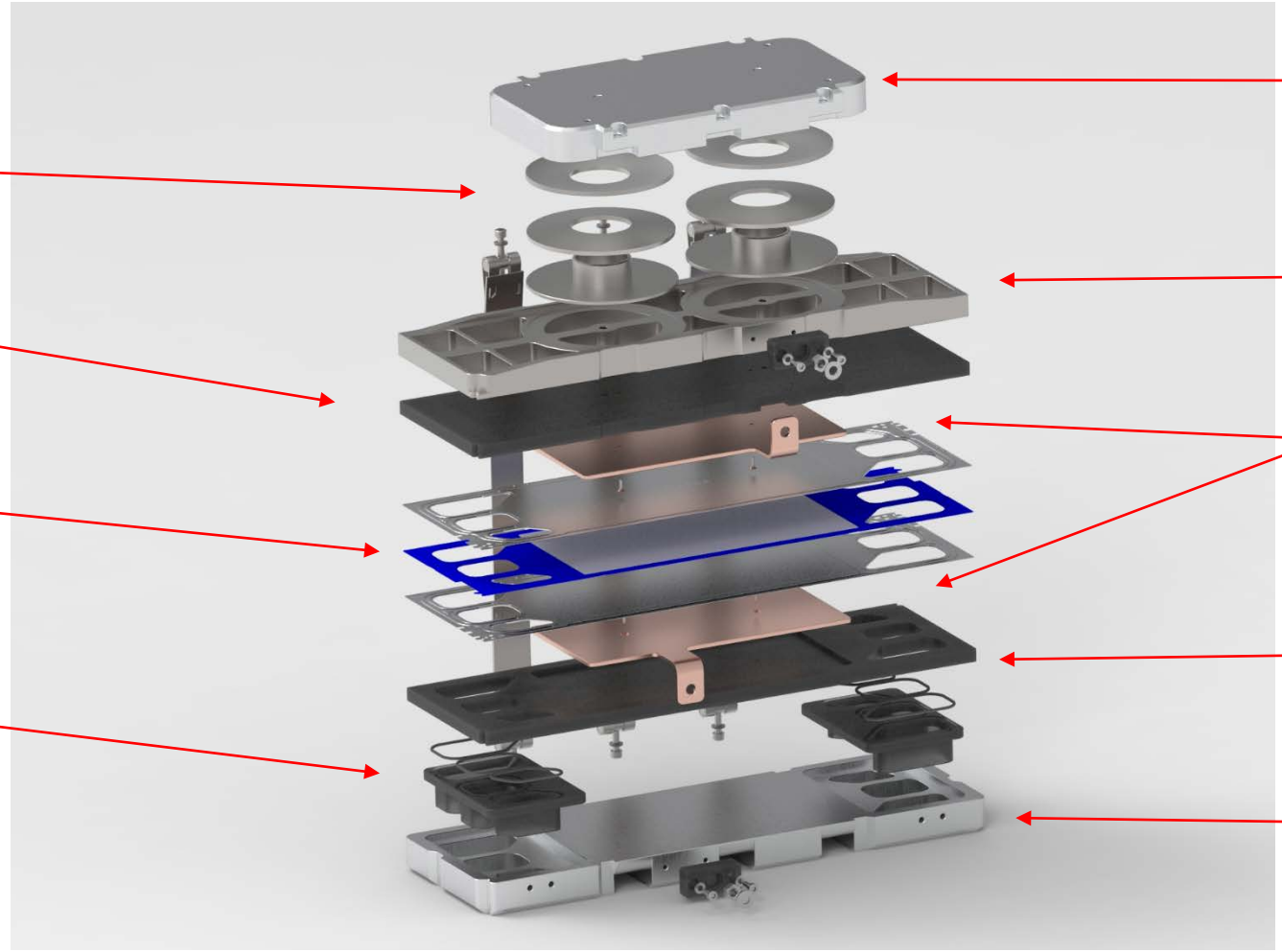
Generic Stack



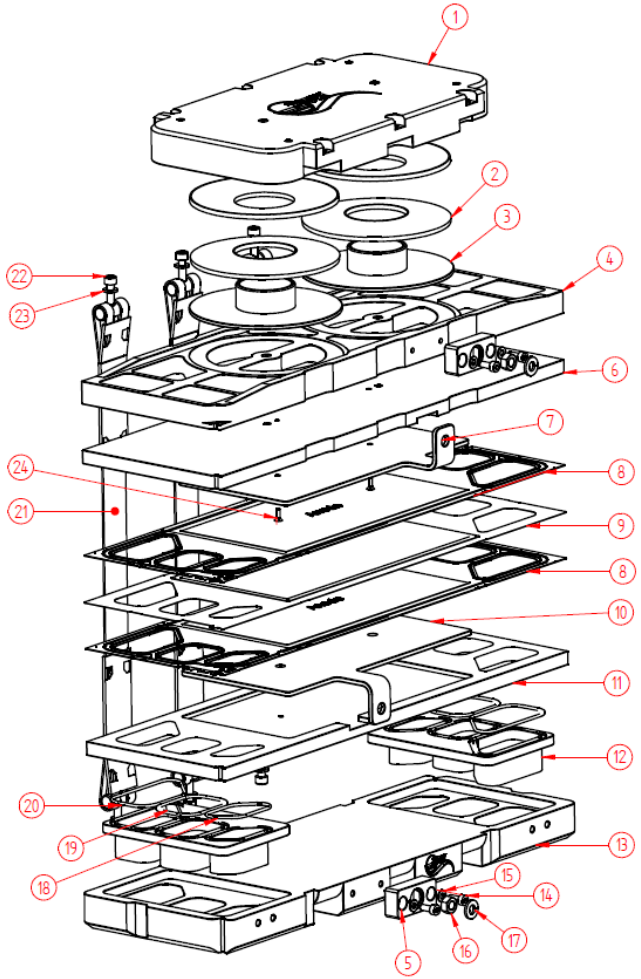
Generic Stack



Generic Stack – Exploded view



Generic Stack – part list



Pos.	Bezeichnung	Material	Anzahl	Bemerkung
1	EP Anode	Al 6061-T6	1	eloxiert, natur
2	Tellerfeder	51CrV4	-	Anzahl abhängig von Stackgröße
3	Führungsdorn	VA 1.4301	2	
4	Spannplatte	VA 1.4301	1	
5	Isolierblock Anode/ Kathode	POM, natur	2	
6	Isolierplatte Anode	POM, natur	1	
7	Stromabnehmer Anode	AlMg3	1	versilbert
8	Bipolarplatte (Wiederholeinheit)	-	-	Anzahl anhängig von Stackgröße
9	MEA-GDL Einheit (Wiederholeinheit)	-	-	Anzahl abhängig von Stackgröße
10	Stromabnehmer Kathode	AlMg3	1	versilbert
11	Isolierplatte Kathode	POM, natur	1	
12	Inserts	POM, natur	2	
13	EP Kathode	Al 6061-T6	1	eloxiert, natur
14	Zylinderschraube M5x12, 8.8	Stahl, verzinkt	4	
15	Unterlegscheibe M5	Stahl, verzinkt	4	
16	Sechskantmutter M8	Stahl, verzinkt	2	
17	Unterlegscheibe M8	Stahl, verzinkt	2	
18	O-Ring, 45x2,5	NBR (70A)	2	
19	O-Ring, 54x2,5	NBR (70A)	2	
20	O-Ring, 66x2,5	NBR (70A)	2	
21	Spannband	HX380LAD	3	
22	Zylinderschraube M6x__, 10.9	Stahl, verzinkt	6	Lange abhängig von Spannbandlänge
23	Unterlegscheibe M6	Stahl, verzinkt	6	
24	Senkschraube M3x10	Stahl, verzinkt	4	

Projektionsmethode 1 – ISO 128

Gewichtkg: 21,29 Maßstab: 1:3,03

Bezeichnung: Stückliste_Exploded_View

Zeichnungsnummer:

Datum Name
Erst. 18.11.2022 bcarna
Ged. 19.01.2023 bcarna
Gepr.

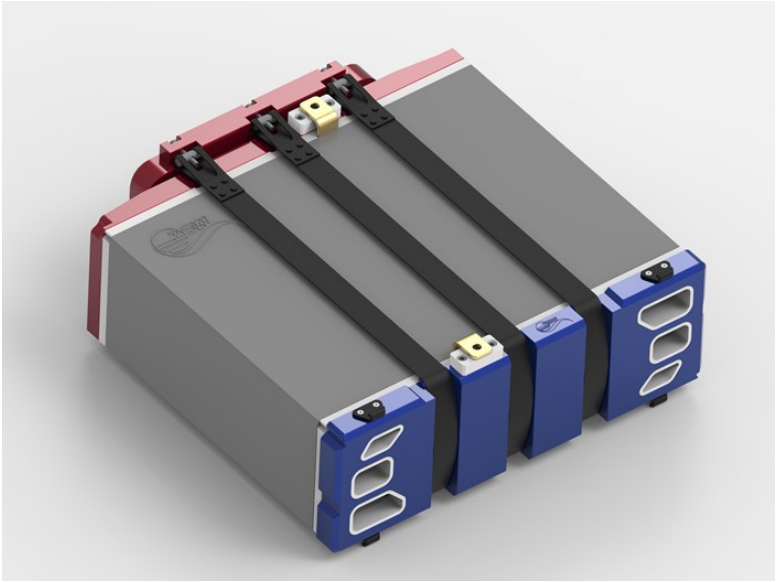
GB-3 ECB

PDM Nummer: 000009489

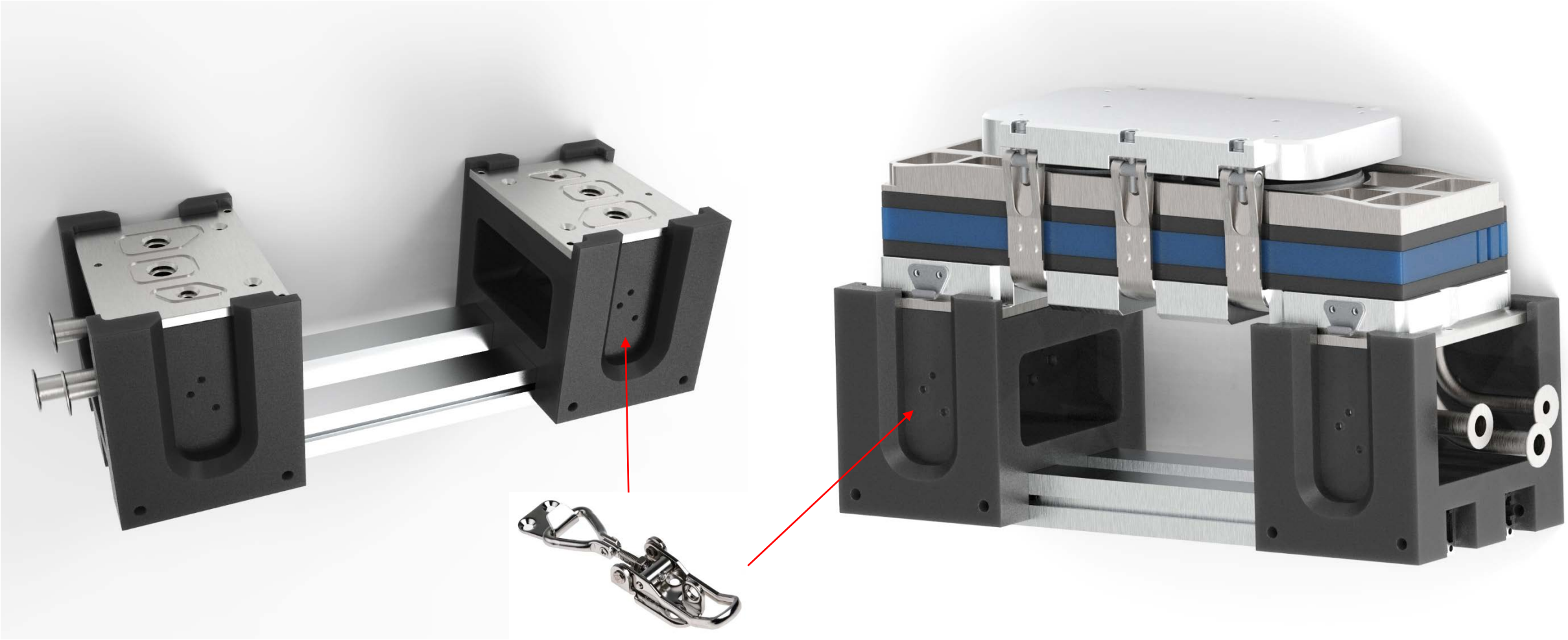
Version: 00.07

A3

Blatt 1 1 Bl.



Generic Stack - Pod



THANK YOU VERY MUCH FOR YOUR ATTENTION

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Stuttgart


Ulm


Ulm eLaB


Ulm HyFaB


Solar test field


Wind test field