HIPER ZAB

CRM free, mid to long term storage for the residential consumer market

Julian Seiler
Deutsches Zentrum für Luft- und Raumfahrtechnik

Power-to-X Symposium Aarhus 2025

European Innovation Council

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HIPERZAB

www.hiperzab.eu

HIgh Performing Electrical Rechargeable Zinc Air Batteries

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HIPERZAB Consortium

CIC energiGUNE
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Politecnico di Torino
1859

SINTEF

IREC
Shaping Energy for a Sustainable Future

HIPER ZAB

DLR

CEGASA

Advenst

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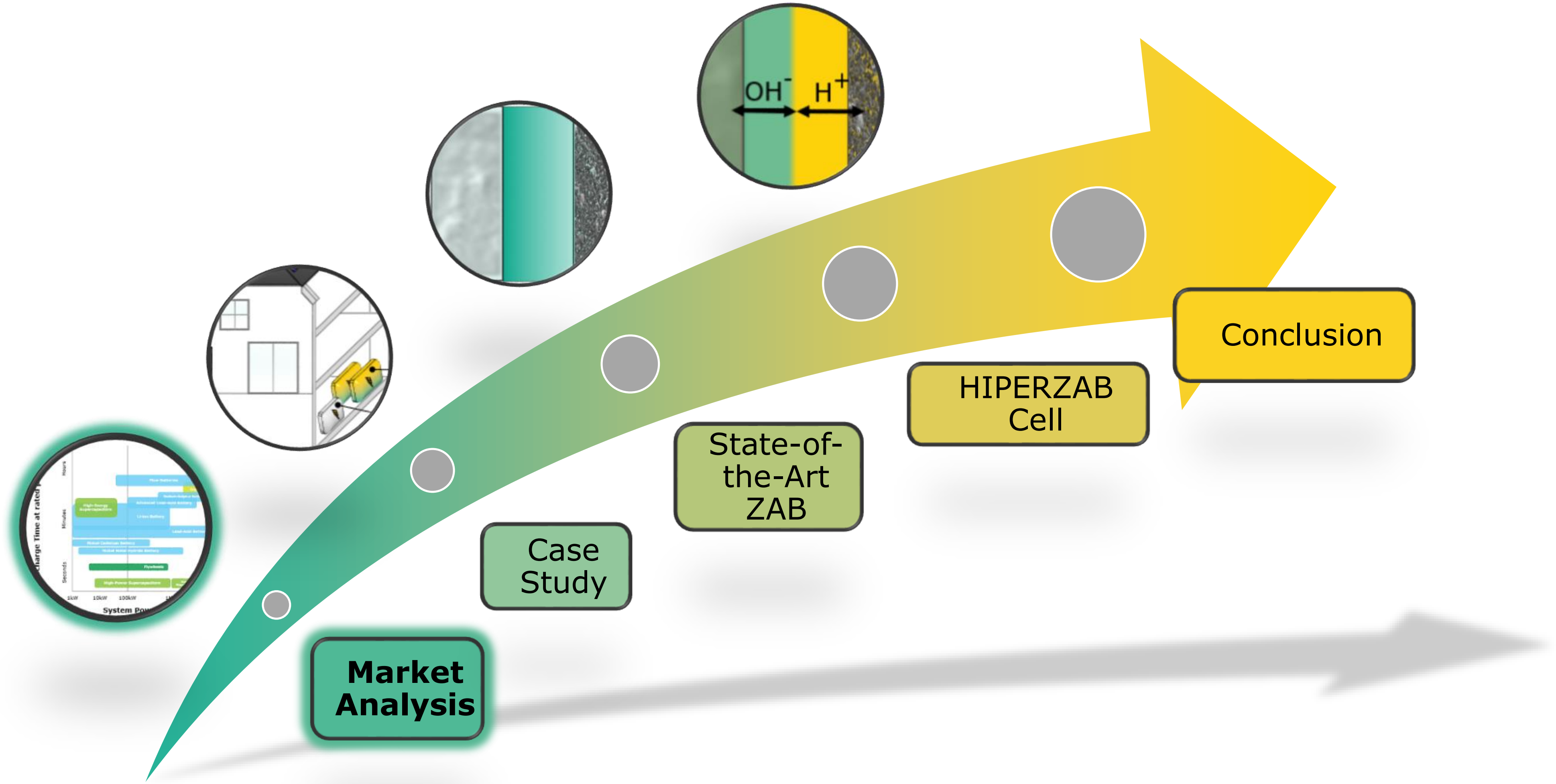

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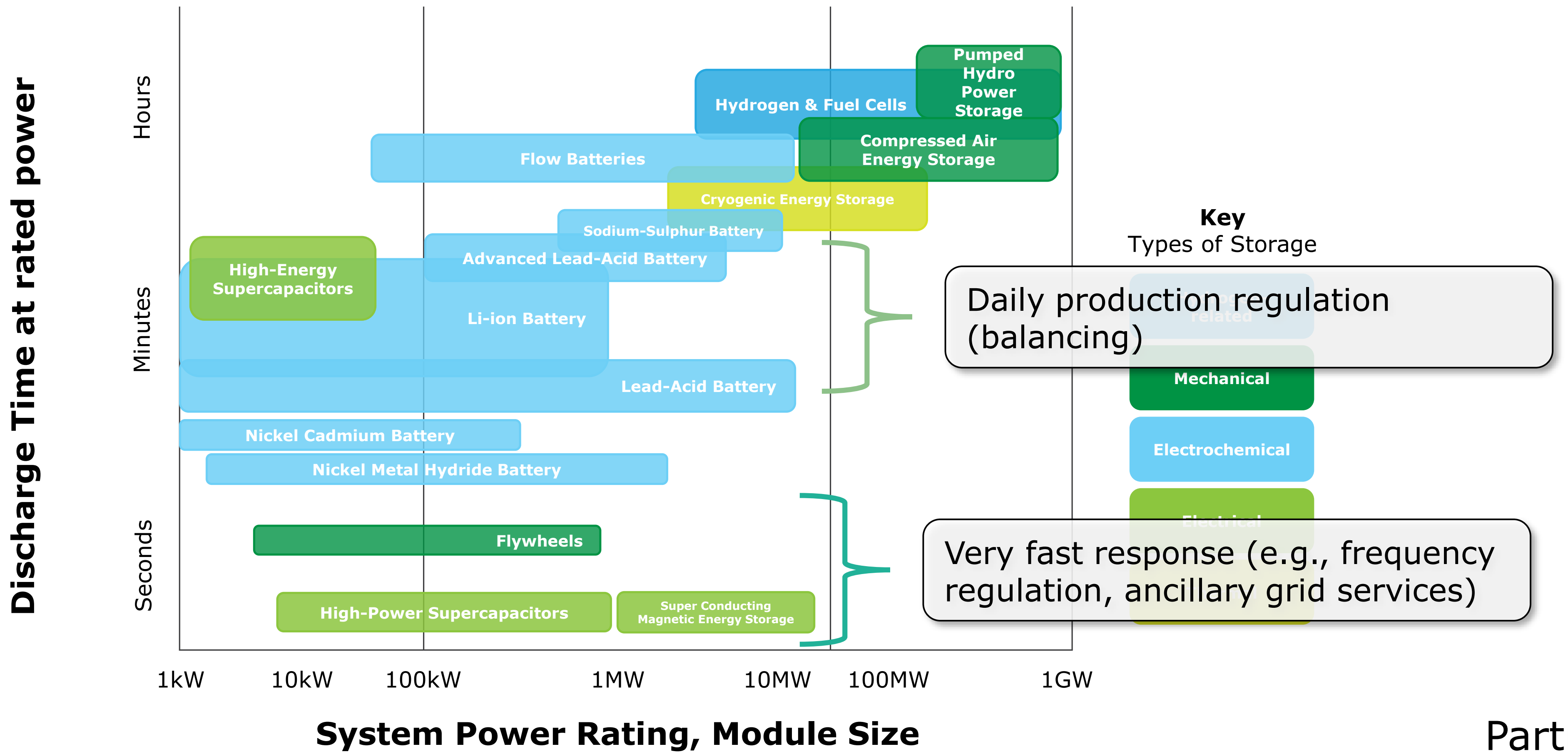
Existing Energy Storage Market



Taylor, P., et al. (2012). "Pathways for energy storage in the UK." Report for the centre for low carbon futures, York.

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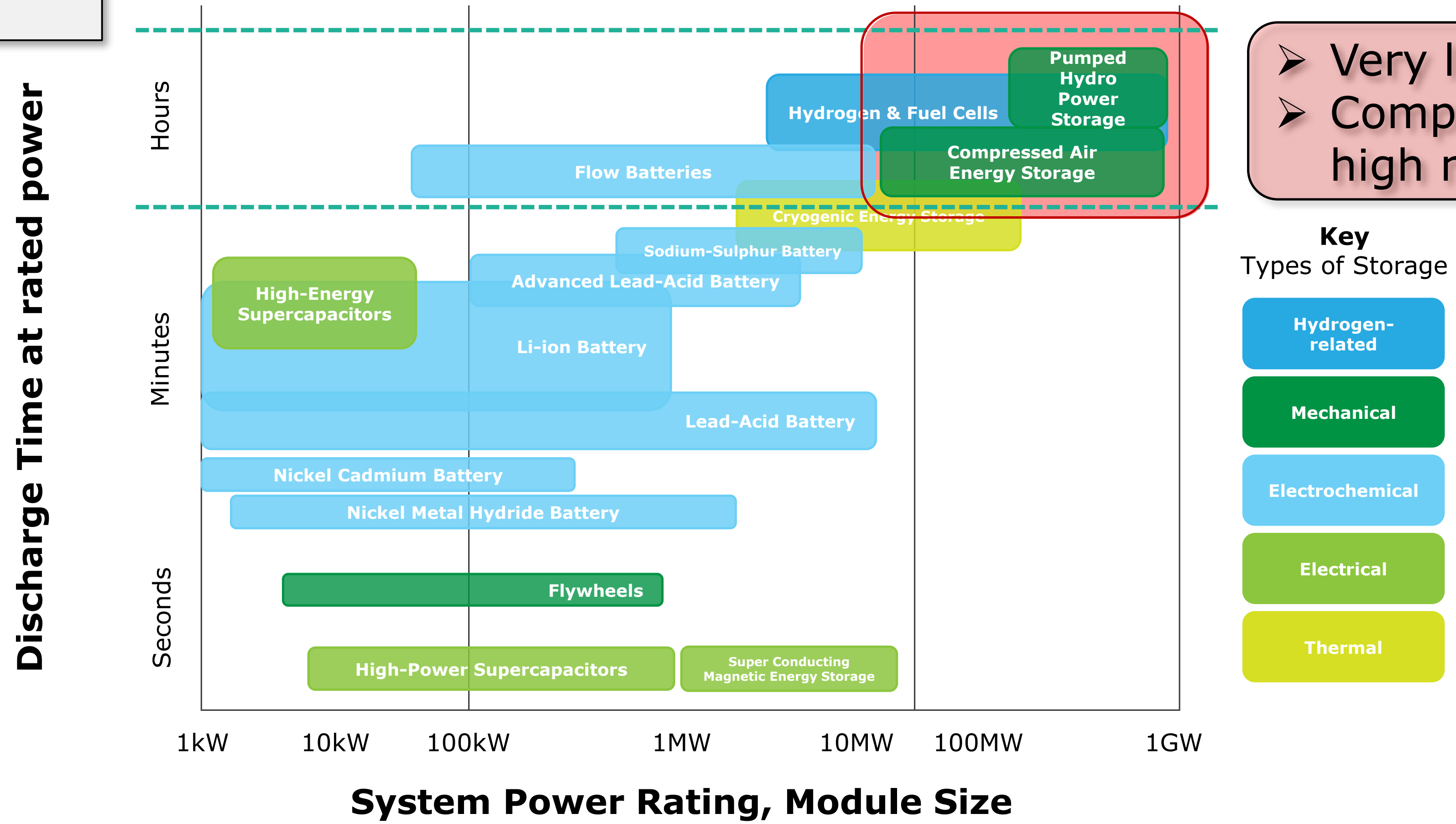
Existing Energy Storage Market

Mid to long term storage



- Very large projects.
- Complex systems with high maintenance.

Partner: CEGASA

European Innovation Council

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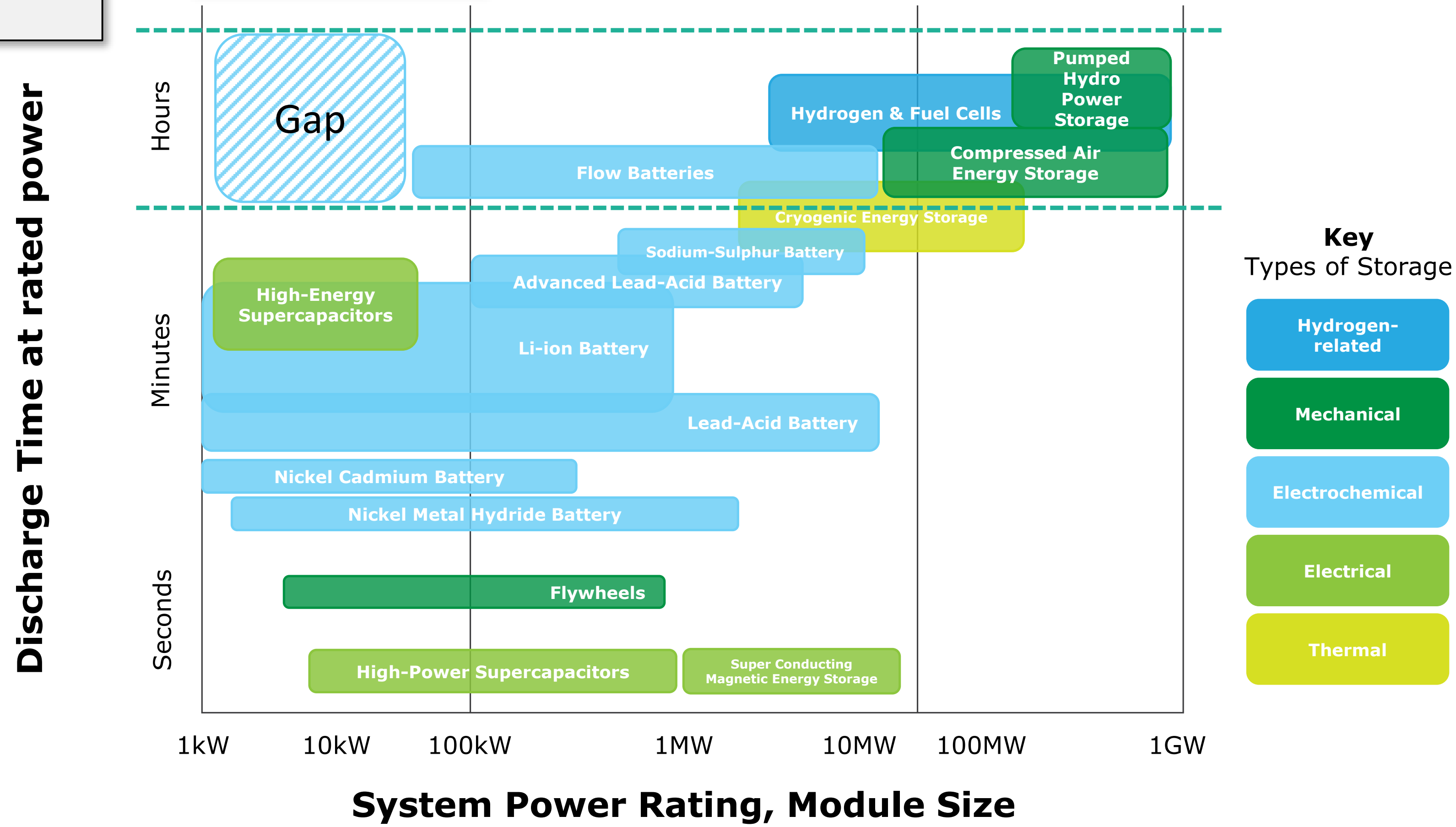
Target: Residential mid-to long-term market

Mid to long term storage

Discharge time:
➢ days

Residential use



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Partner:
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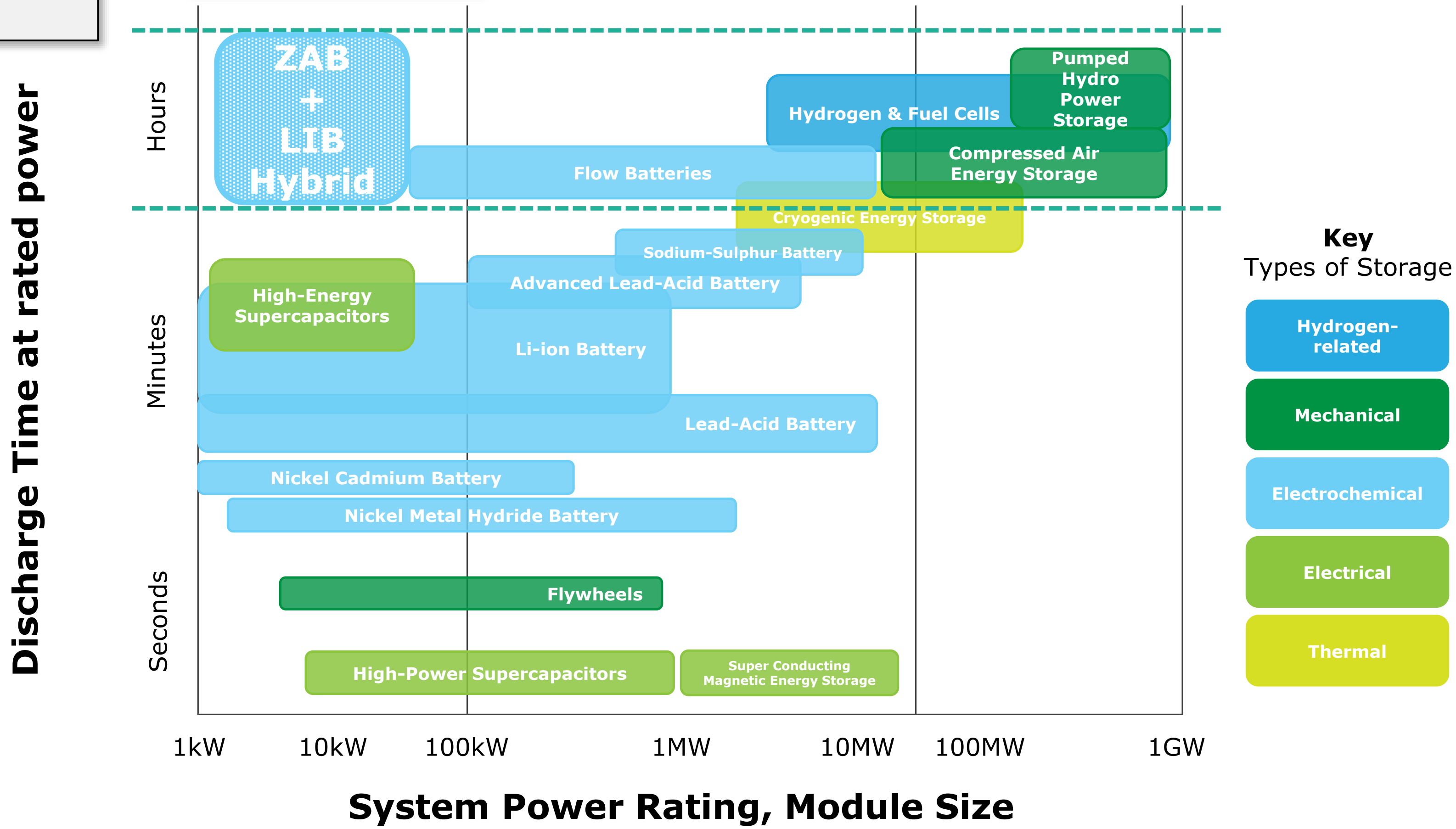
Target: Residential mid-to long-term market

Mid to long term storage

Discharge time:
➢ days

➢ COSTS

Residential use



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Partner: CEGASA

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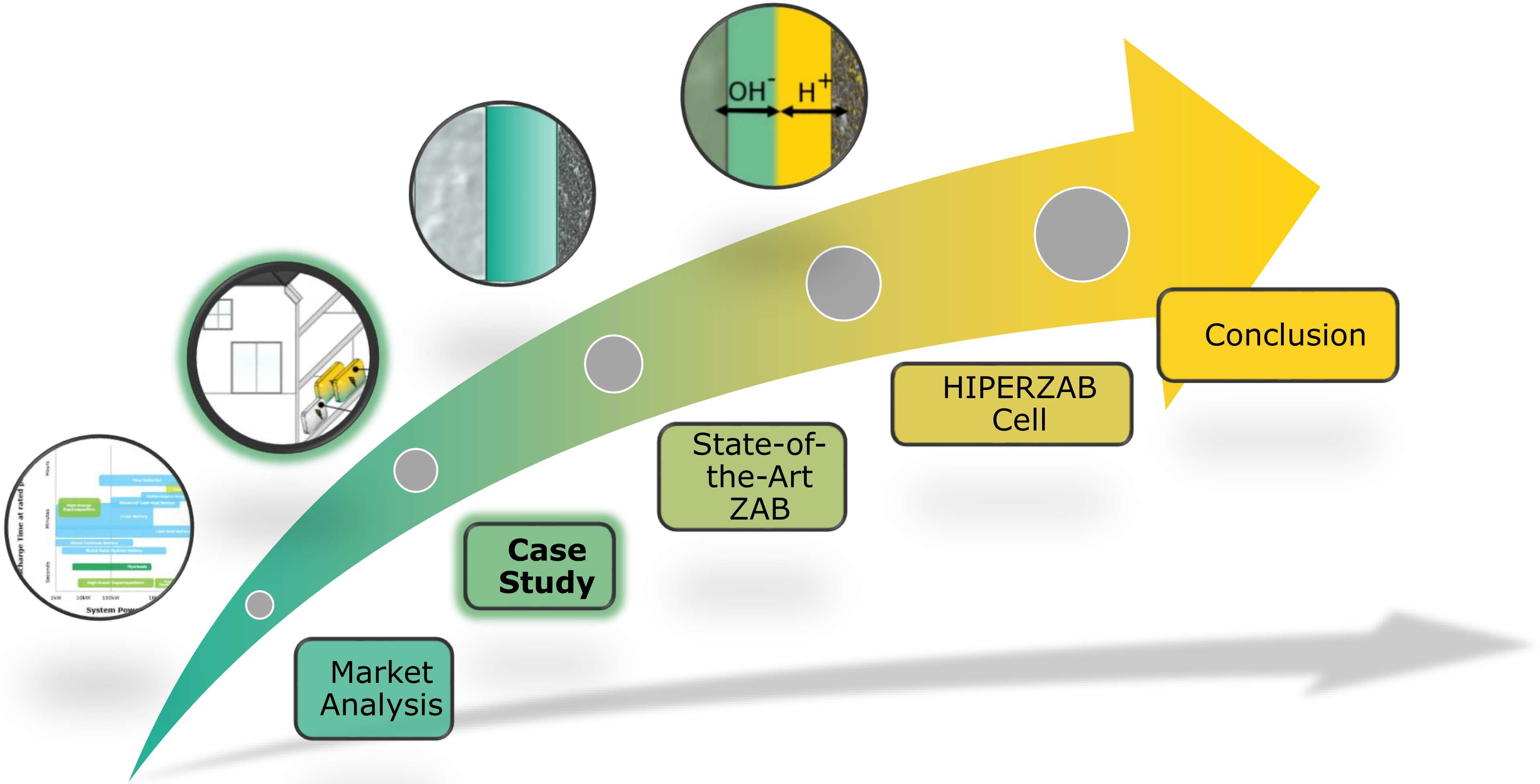

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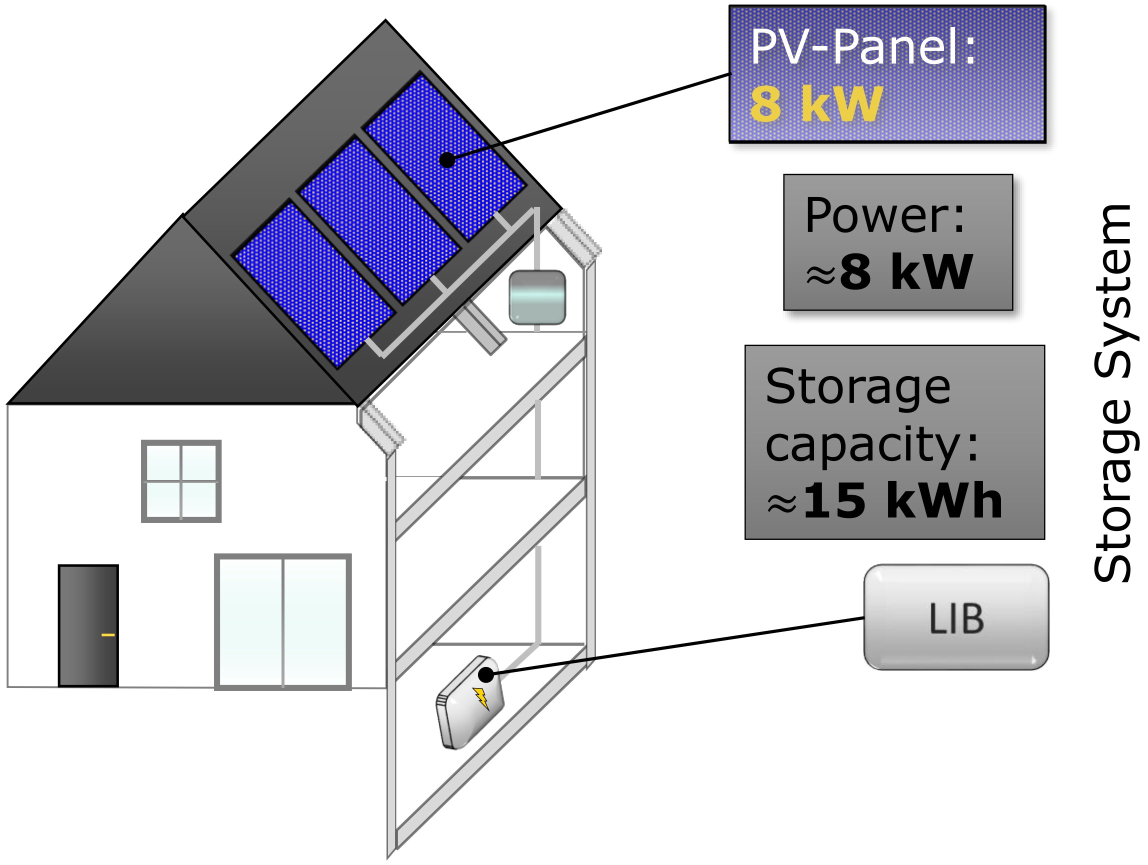
Case Study



Typical client requirements

Discharge Power	8kW
Charge Power	8kW
Energy	50kWh
Durability	20 years

DoD	# Total	Avg./ year	Occurrence
100%	2	0.1	
80%	50	2.5	Specific days
60%	200	10	Mainly in winter
40%	5000	250	
20%	50000	2500	Mainly in summer
<20%	>50000		

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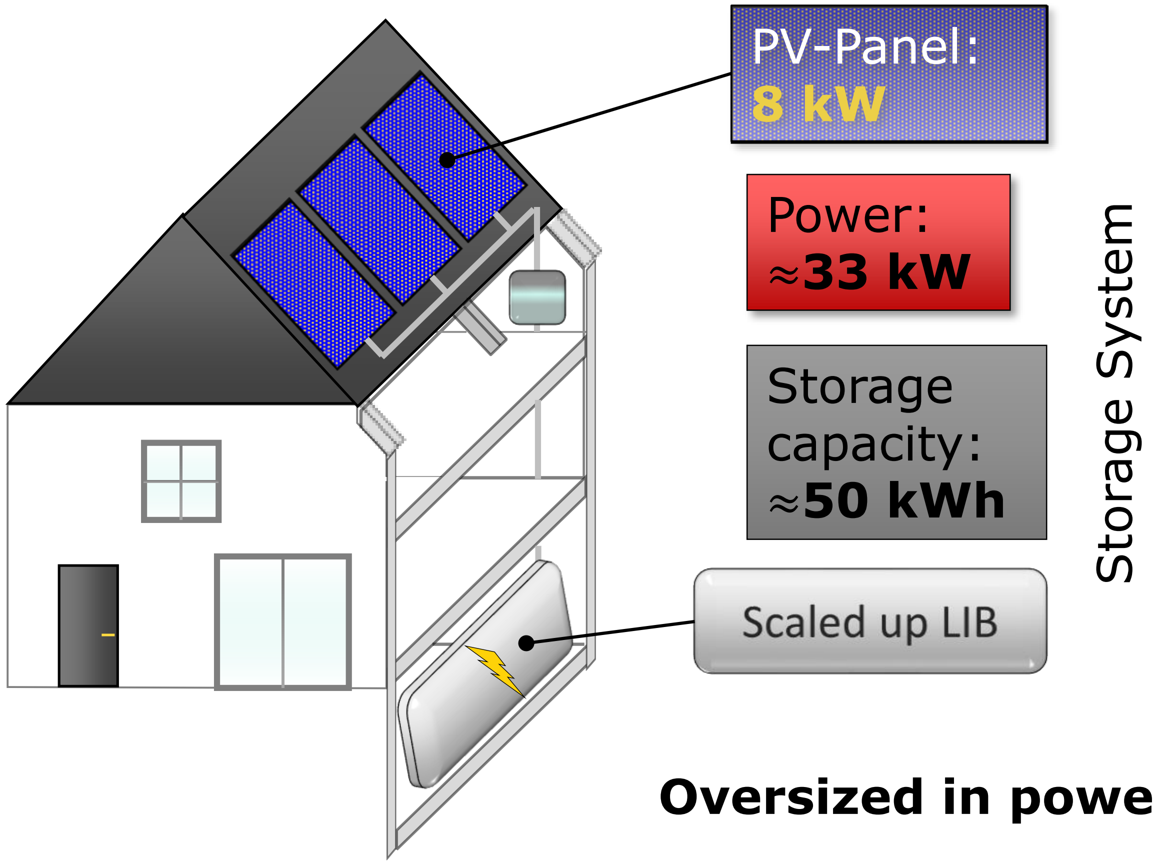
Case Study



Oversized in power!

Typical client requirements	
Discharge Power	8kW
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Partner:
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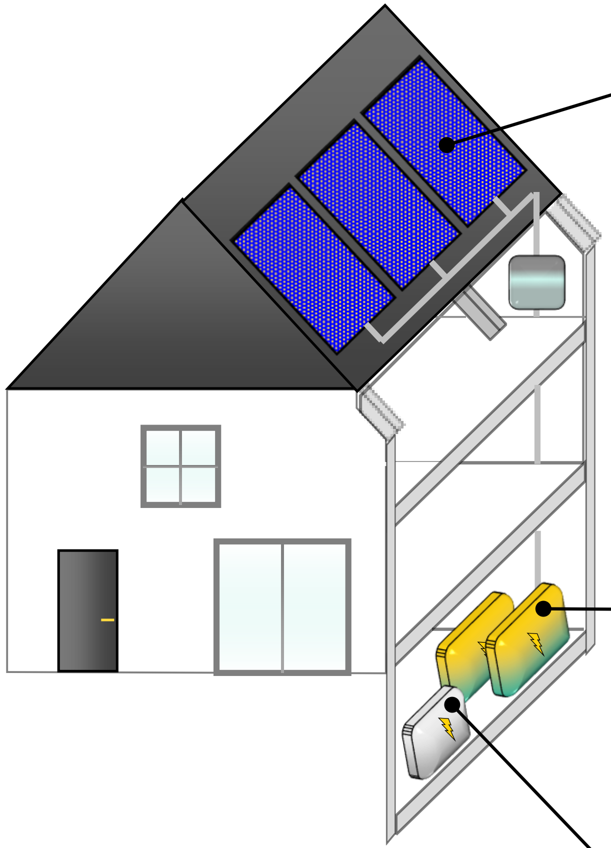

PV-Panel:
8 kW

Power:
≈10 kW

Storage capacity:
≈50 kWh

2 x ZAB

- low C-rates
- **Cheap**
- deeper DoD,
- longer storage time

1 x LIB

- fast response

Typical client requirements	
Discharge Power	8kW
Charge Power	8kW
Energy	50kWh
Durability	20 years

DoD	# Total	Avg./ year	Occurrence
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Partner:
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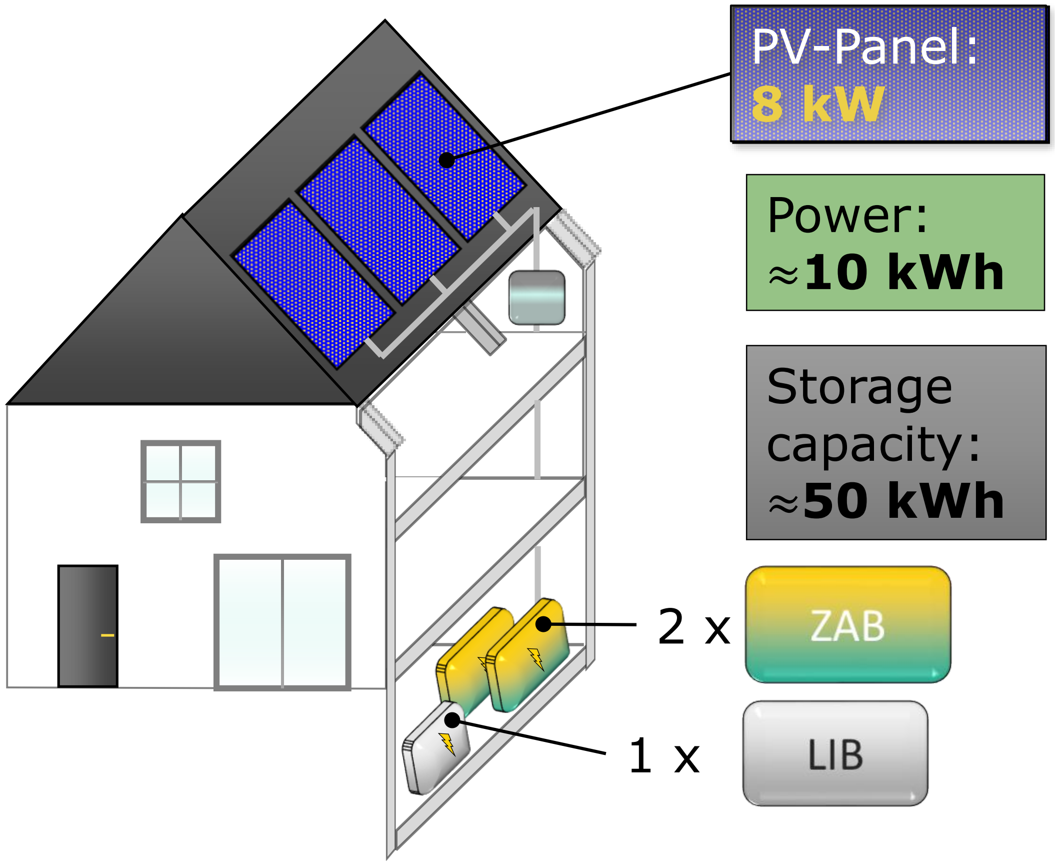
Case Study



? **Costs**

Requirements ?

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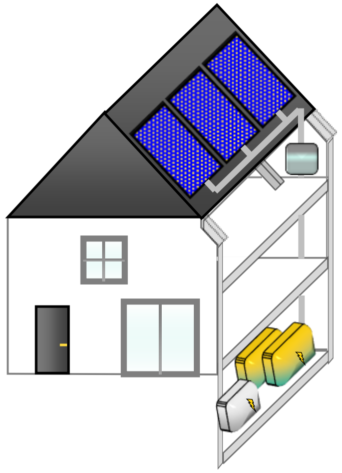
Case Study



Costs

Drawbacks:

- Residential use will not receive volume discount

Advantages:

- Easier to adapt to needs
- ➢ reduce costs

ZAB primary	LIB
50-100 €/kWh	750–1.250 €/kWh

➢ Costs of secondary ZAB?

Requirements

- Low cost ZAB
- Simple, maintenance free solutions

- Self breathing bifunctional air electrode
- CRM “free” solutions
- Water based system
- **Cyclability**

Partner:
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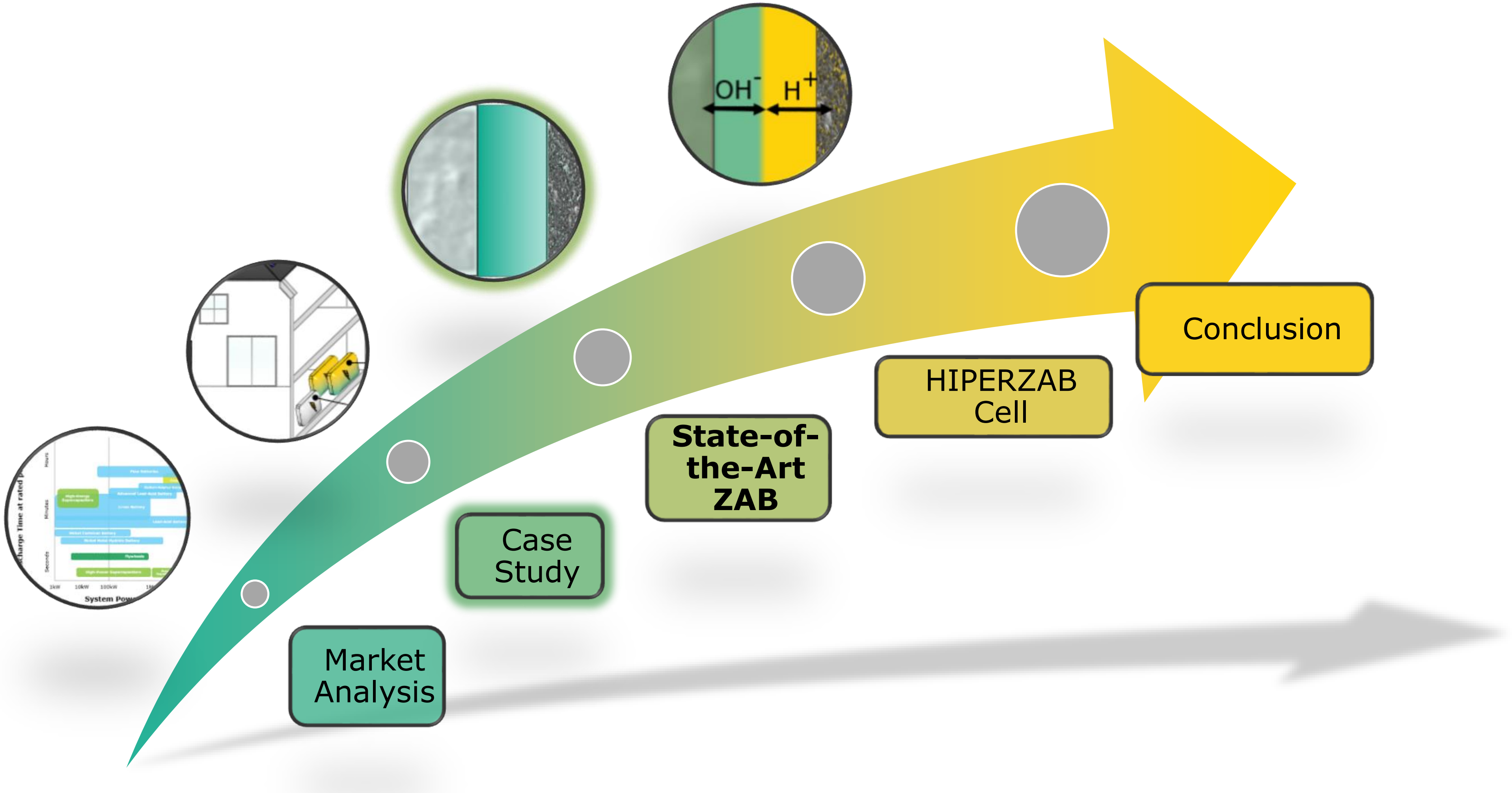

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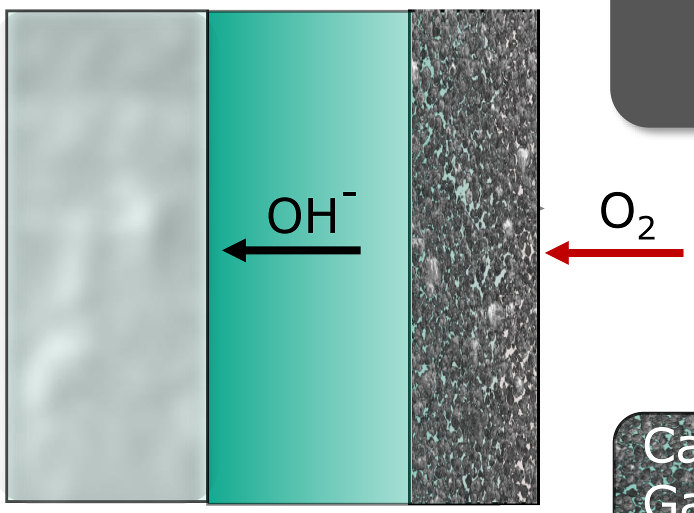
State-of-the-Art ZABs

ΔU = 1.6V / 1.4V (Theo./Real)

$$2\,Zn + 8\,OH^- \rightleftharpoons 2\,Zn(OH)_4^{2-} + 4\,e^-$$

$$O_2 + 2\,H_2O + 4e^- \rightleftharpoons 4\,OH^-$$



Anode:
Zinc powder

Electrolyte:
KOH 6M

Cathode
Gas Diffusion
Electrode

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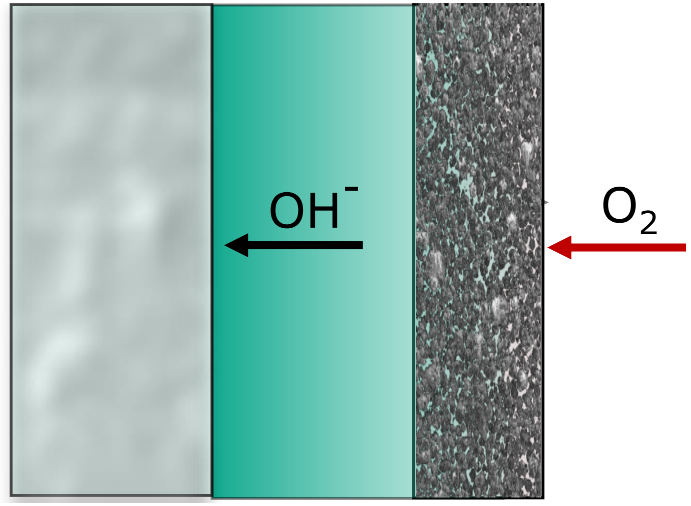
State-of-the-Art ZABs



	Limitations
Anode: Zinc powder	• Loss of structure in Zn-electrode • Passivation
Electrolyte: KOH 6M	• Precipitation of carbonates due to CO_2 absorption • Leakage
Cathode Gas Diffusion Electrode	• Sluggish OER/ORR (RTE ≈ 60%) • Most OER catalyst are CRM • Most used materials unstable during OER

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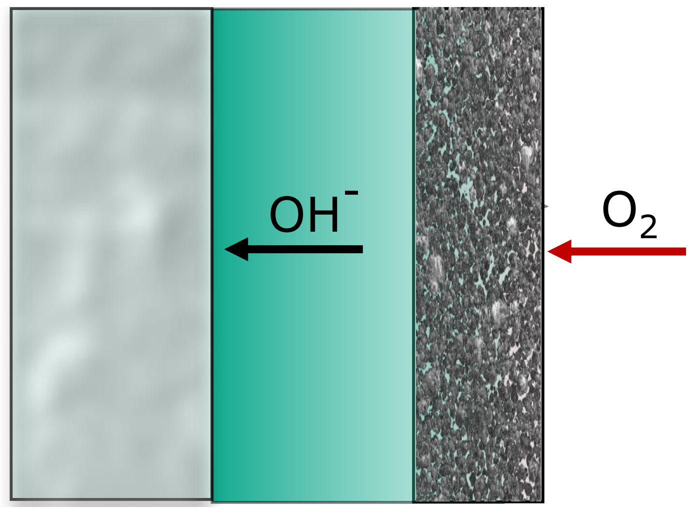
State-of-the-Art ZABs



Limitations

	Limitations
Anode: Zinc powder	**No Cyclability** • Loss of structure in Zn-electrode • Passivation
Electrolyte: KOH 6M	**Degradation** • Precipitation of carbonates • Leakage
Cathode Gas Diffusion Electrode	**Uneconomical** • Sluggish OER/ORR (RTE ≈ 60%) • Most used materials unstable during OER

➢ All components have to improved

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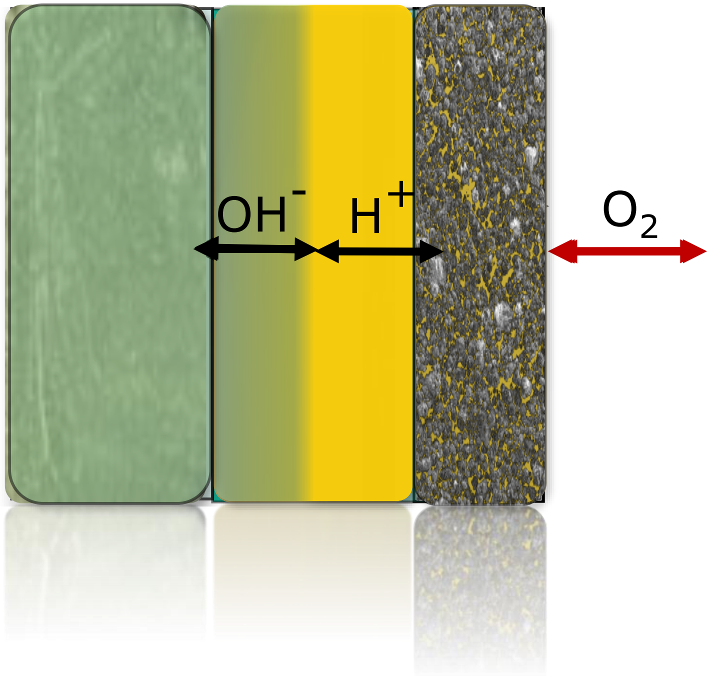
HIPERZAB Cell



SoA Cell	HIPERZAB Cell	Benefit
Anode: Zinc powder	Anode: 3D Zinc / Biopolymer Composite	• Structure stabilized
Electrolyte: KOH 6M	Electrolyte: Bilayer Gel-Polymer-Electrolyte	• pH Gradient to suppress CO_2 absorption
Cathode Gas Diffusion Electrode	Cathode Acidic GPE Gas Diffusion Electrode	• Prevent leakage • Different reaction

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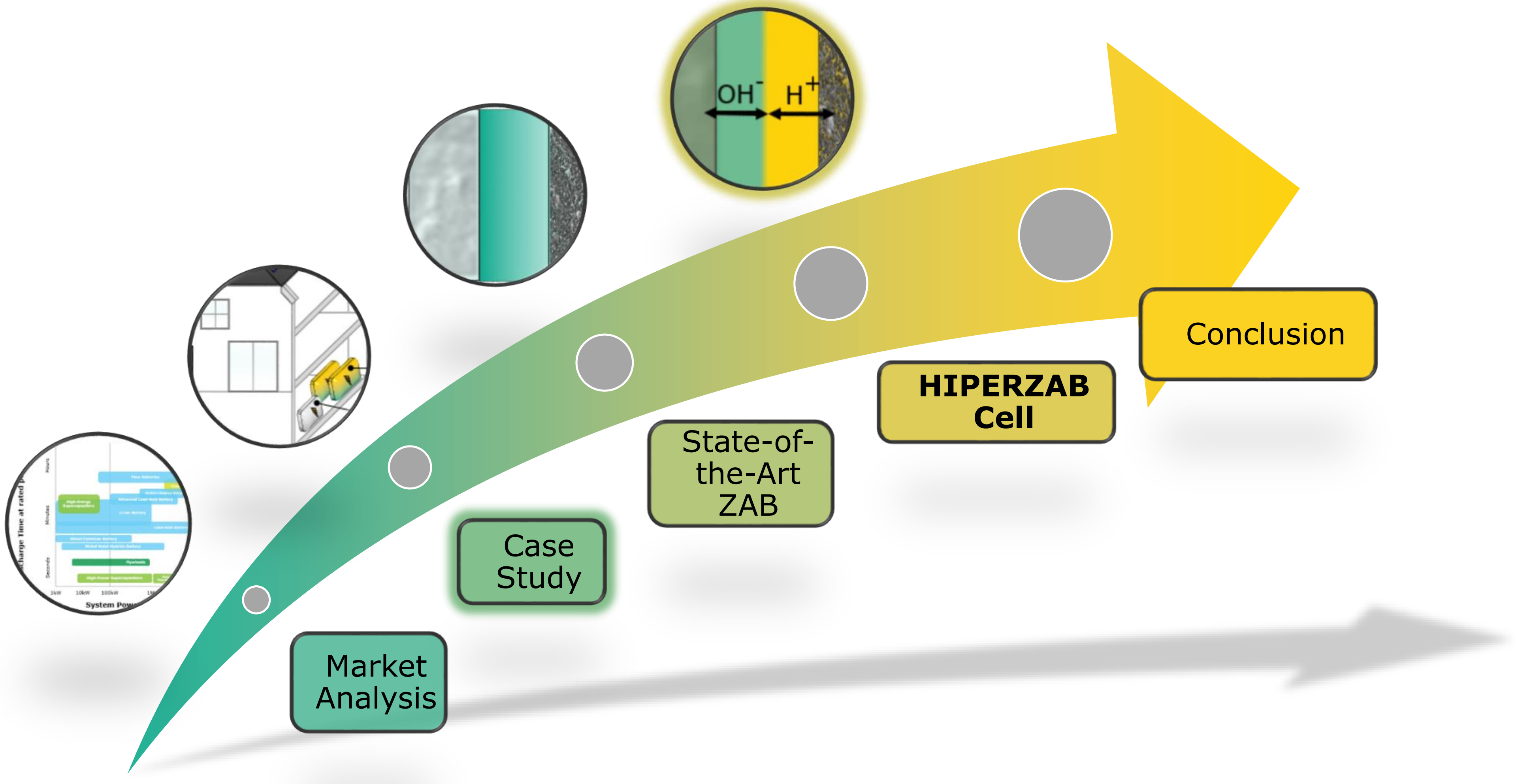

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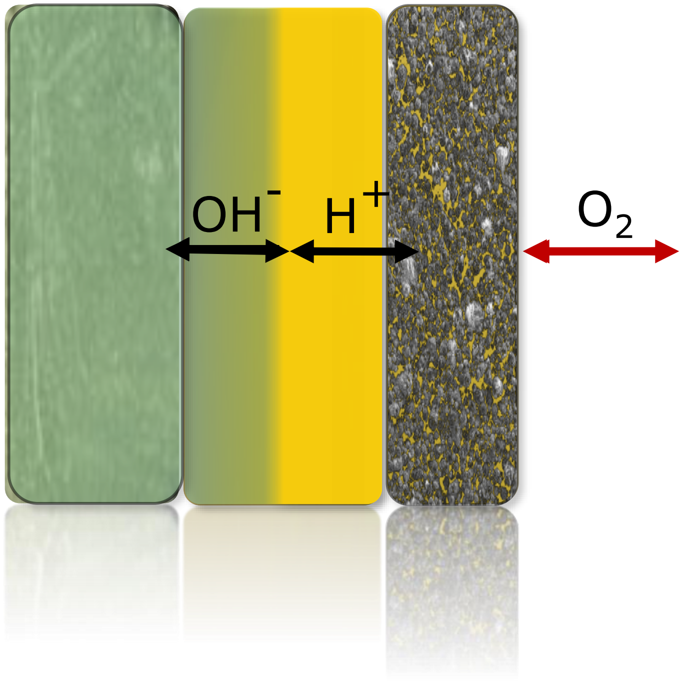
HIPERZAB Cell



SoA Cell	HIPERZAB Cell	Progress M20
Anode: Zinc powder	Anode: 3D Zinc / Biopolymer Composite	
Electrolyte: KOH 6M	Electrolyte: Bilayer Gel-Polymer-Electrolyte (GPE)	
Cathode GDE	Cathode Acidic GPE Gas Diffusion Electrode	

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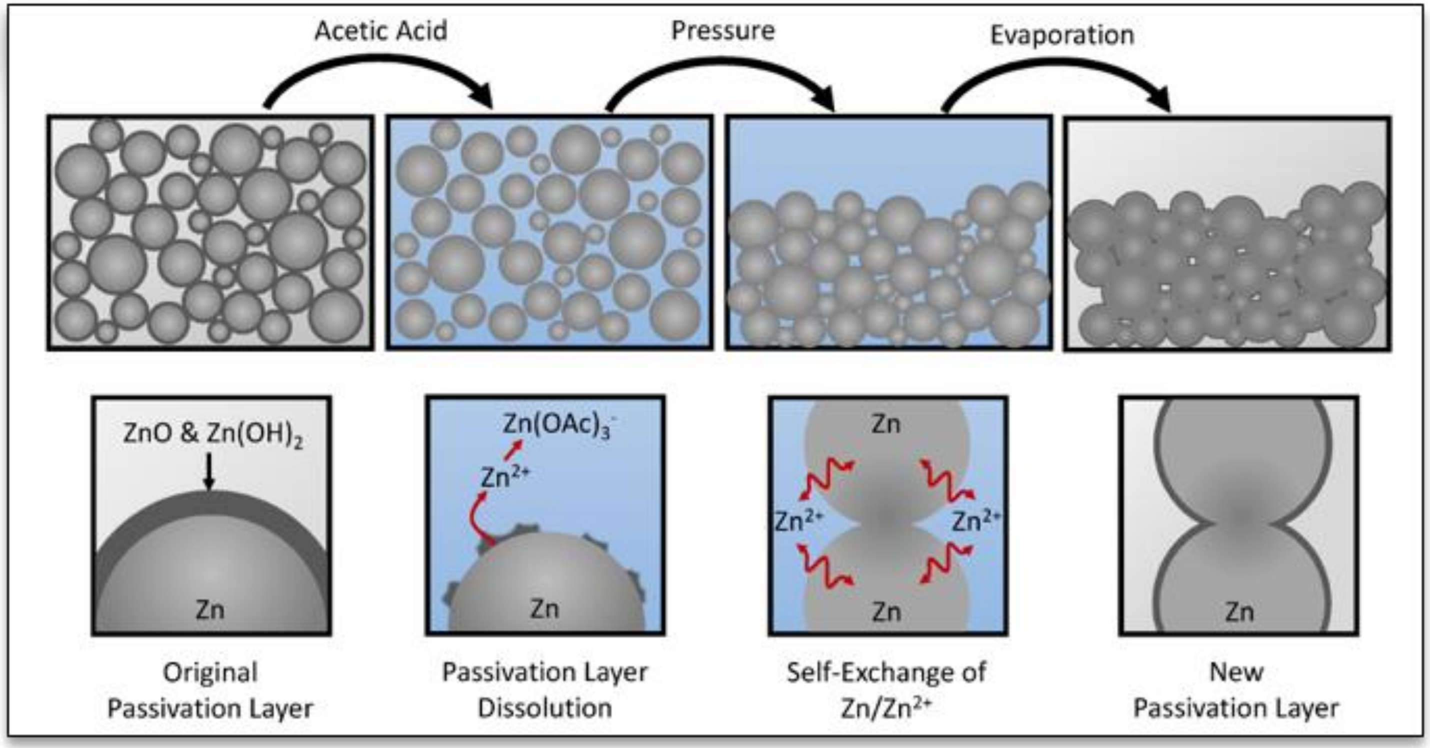
HIPERZAB Cell

Anode:
3D Zinc / Biopolymer Composite

Room-Temperature Cold Sintering Process (RT-CSP)



Partner: SINTEF

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[1] Jayasayee, K., Clark, S., King, C., Dahl, P. I., Richard Tolchard, J., & Juel, M. (2020). Cold sintering as a cost-effective process to manufacture porous zinc electrodes for rechargeable zinc-air batteries. *Processes*, *8*(5), 592.

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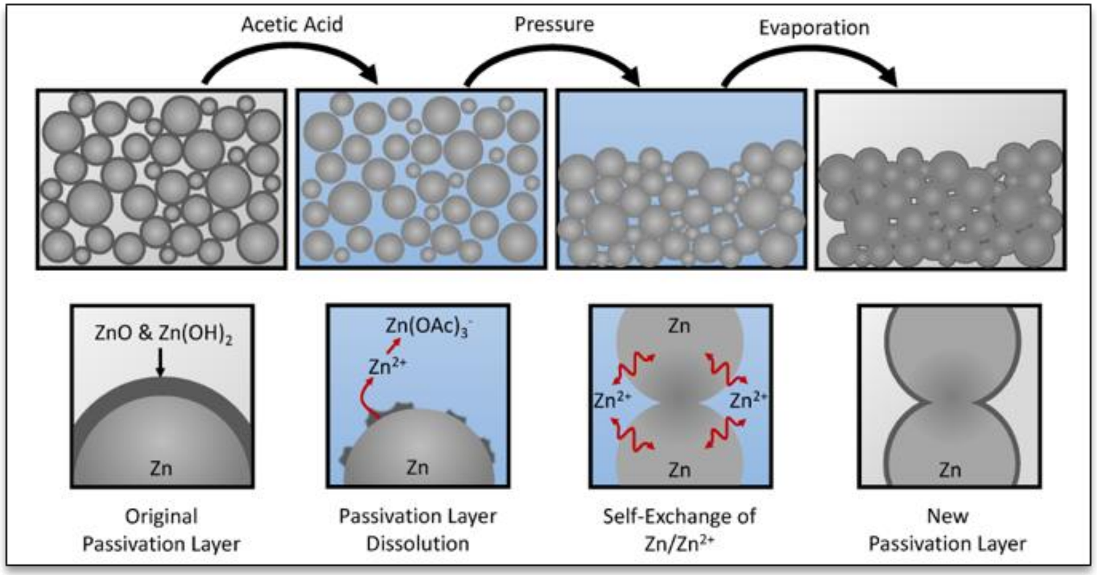
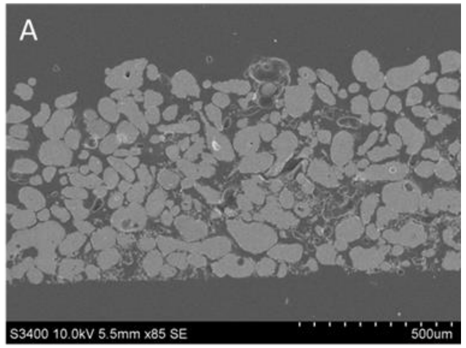
HIPERZAB Cell

Anode:
3D Zinc / Biopolymer Composite



Development of 3D Zn electrode by RT-CSP

- Use established RT-Sintering approach [1] to produce a porous Zn-electrode
  - ✓ Optimize composition and procedure for HIPERZAB
  - ✓ Improved porosity by 16% compared to SoA [1]



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SINTEF

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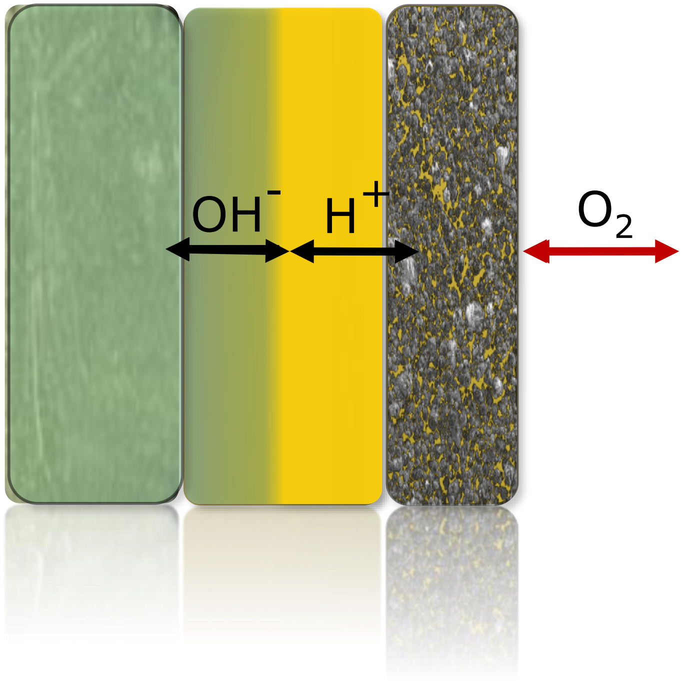
HIPERZAB Cell



SoA Cell	HIPERZAB Cell	Progress M20
Anode: Zinc powder	Anode: 3D Zinc / Biopolymer Composite	• Improved 3D Zn Anode produced with RT-CSP • Ongoing: Integration of polymer and EC testing
Electrolyte: KOH 6M	Electrolyte: Bilayer Gel-Polymer-Electrolyte (GPE)	
Cathode GDE	Cathode Acidic GPE Gas Diffusion Electrode	

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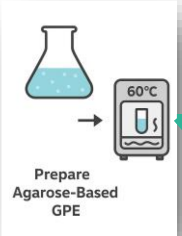
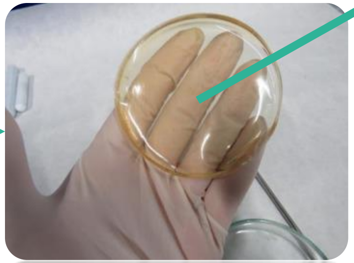
HIPERZAB Cell

Electrolyte: Bilayer Gel-Polymer-Electrolyte (GPE)

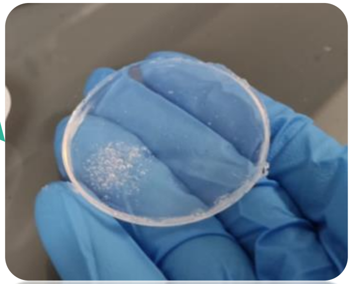


GPEs based on Biopolymers

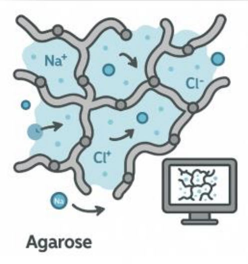
- Sustainable & eco-friendly
- 1-pot formulation



Alkaline agarose GPE

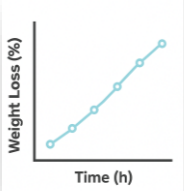


Acidic agarose GPE



Molecular modelling

- Classical molecular dynamics of agarose polymer in alkaline electrolyte
- Investigation of structural features and transport properties
- **Challenge:** Alkaline pH simulations require identification of decomposition products
- **Achievement**: Developed a classical force field for agarose



Challenges

- Tuning of agarose GPE for increased ageing & mechanical stability

GPE crosslinking for improved electrolyte retention and long-term stability

- Study of various crosslinkers
- Characterization of impact on mechanical and electrochemical properties

Partners:

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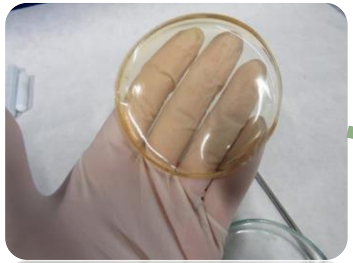
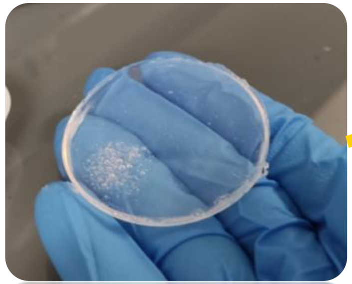
Electrolyte: Bilayer Gel-Polymer-Electrolyte (GPE)

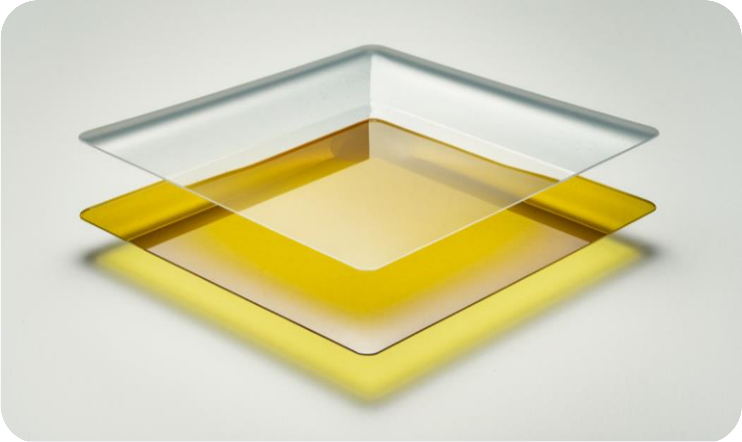


Alkaline agarose GPE



Acidic agarose GPE

Integration started



Graphical representation of the acid-alkaline bilayer

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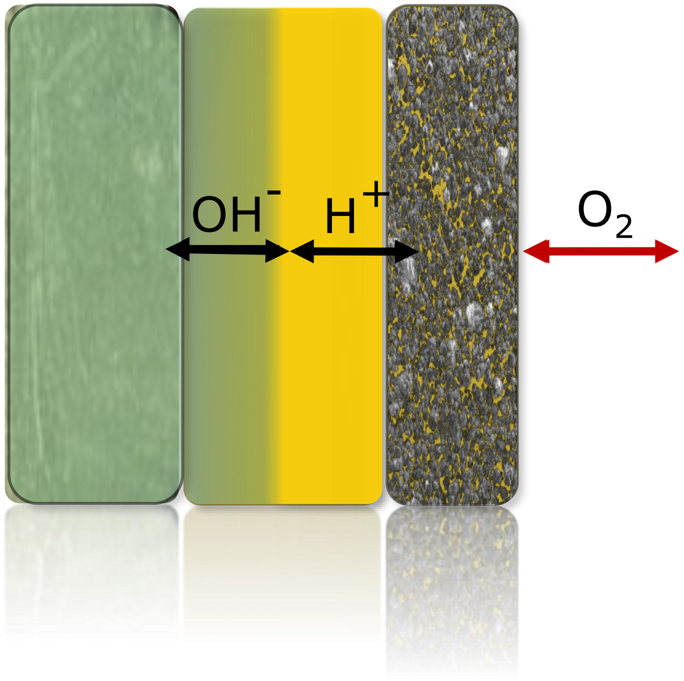

SoA Cell	HIPERZAB Cell	Progress M20
Anode: Zinc powder	Anode: 3D Zinc / Biopolymer Composite	• 3D Zn Anode produced with RT-CSP • Ongoing: Integration of polymer and EC testing
Electrolyte: KOH 6M	Electrolyte: Bilayer Gel-Polymer-Electrolyte (GPE)	• Improved GPE stability • Ongoing: Integration of polymer and EC testing
Cathode GDE	Cathode Acidic GPE Gas Diffusion Electrode	

HIPERZAB Cell

Cathode
Acidic GPE Gas
Diffusion Electrode

Why is the round-trip-efficiency low?

The oxygen reactions differ in their needs!

	Evolution Reaction	Reduction Reaction
Type	2-phase reaction	3-phase reaction
Electrolyte concentration	High	Low (solubility of oxygen)
Transport	Good bubble removal	Maximum contact line length

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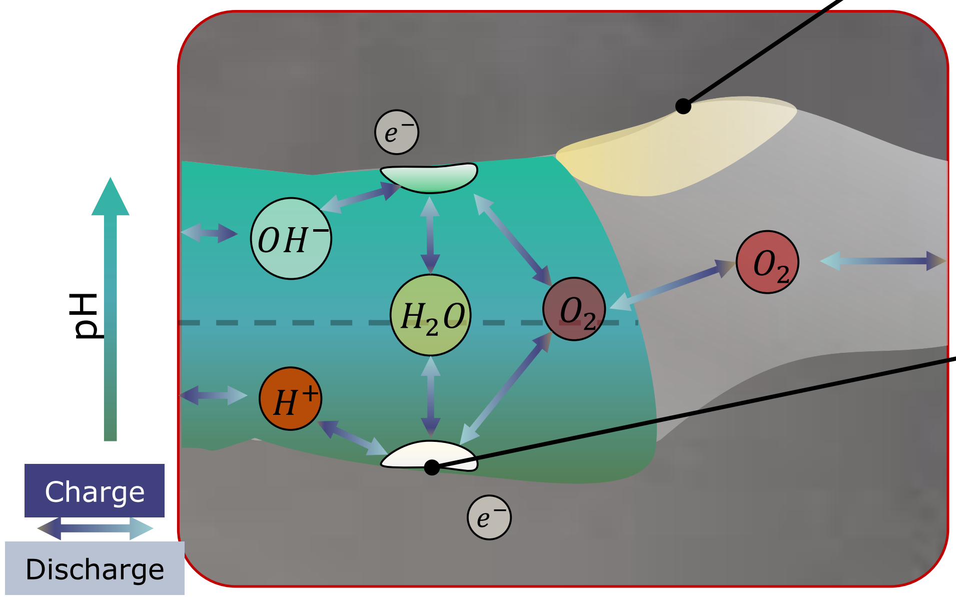
HIPERZAB Cell

Cathode
Acidic GPE Gas
Diffusion Electrode



Gas Diffusion Layer

Challenge
Finetune hydrophobicity and transport processes

Progress
ICVD produces desired layers

Catalyst

Challenges
- Find a CRM free bifunctional catalyst high entropy perovskite

Too many possible combinations
- Method development: Large area pulsed laser synthesis for high throughput experiments using ML to find new materials
- Speeding up optimization of materials

Partners:
Advenst IREC DLR

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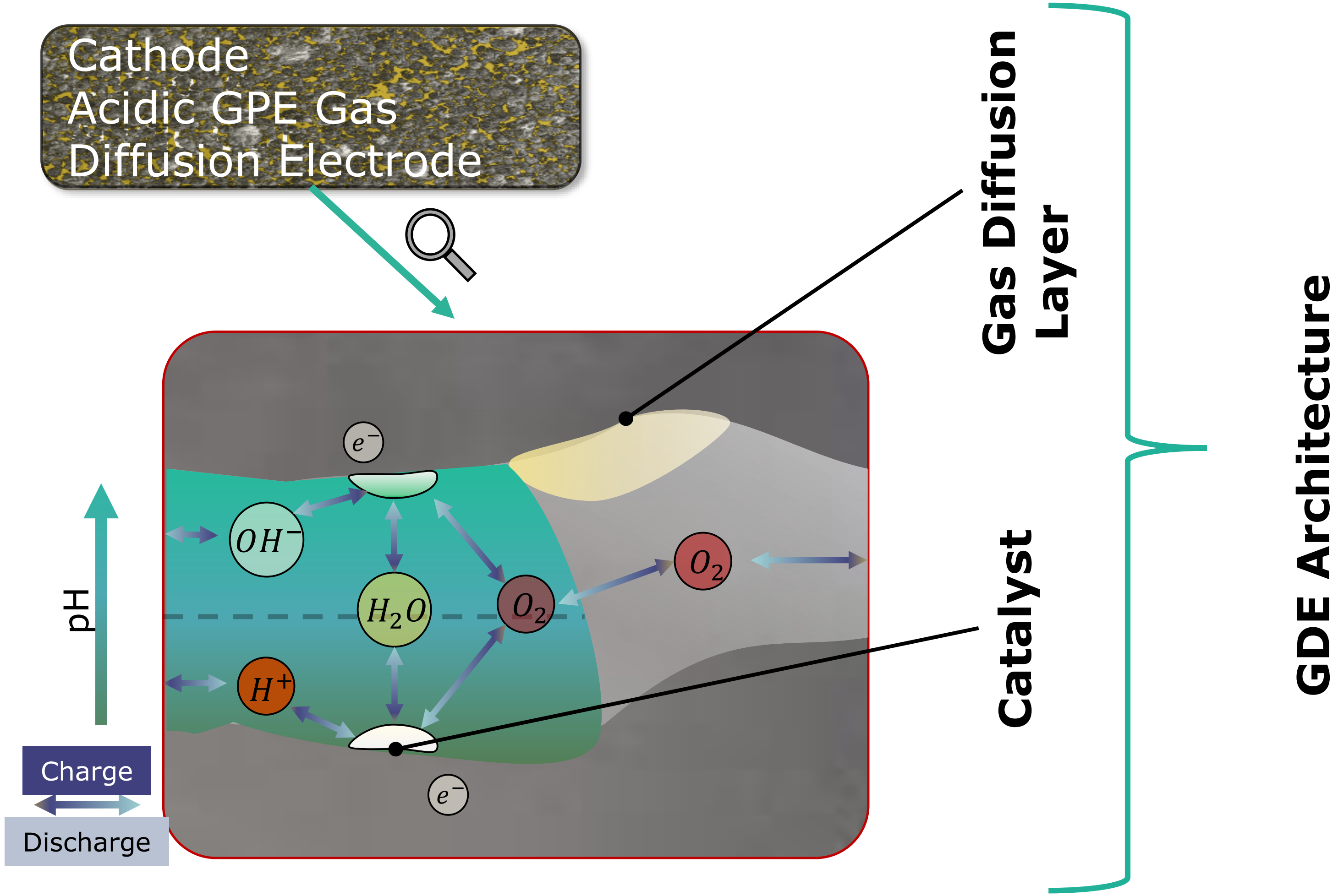

Challenges

Stability

- OER conditions too harsh for most substrate materials (e.g. carbon)
  - ➢ Nickel based electrode

Structure

- Optimize pore size and porosity for
  - optimal gas transport
  - optimal reaction conditions

  in combination with hydrophobic layer

Partners:

Advenst
IREC Shaping Energy for a Sustainable Future
DLR

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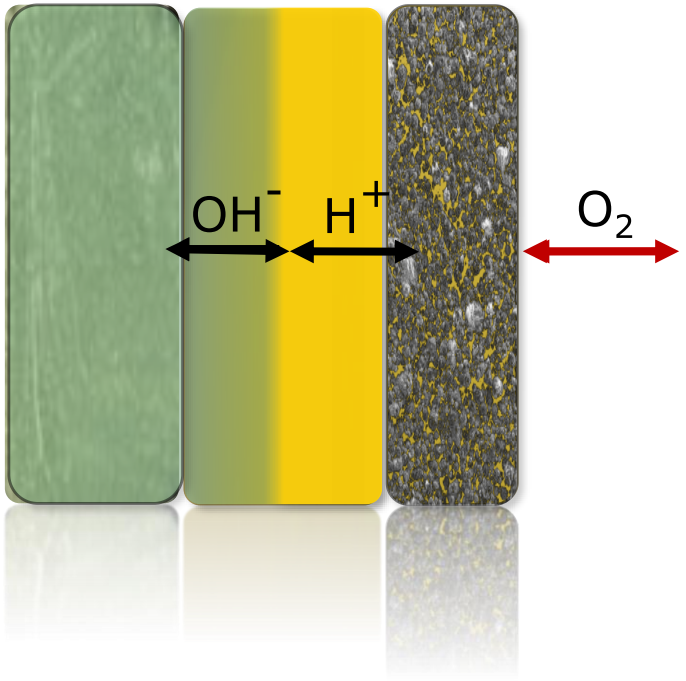

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Electrolyte: KOH 6M	Electrolyte: Bilayer Gel-Polymer-Electrolyte (GPE)	• Improved GPE stability and mitigated neutralization • Ongoing: Integration of polymer and EC testing
Cathode GDE	Cathode Acidic GPE Gas Diffusion Electrode	• GDL production method established • High throughput screening for catalyst in build up • GDE materials identified, fabrication method in development

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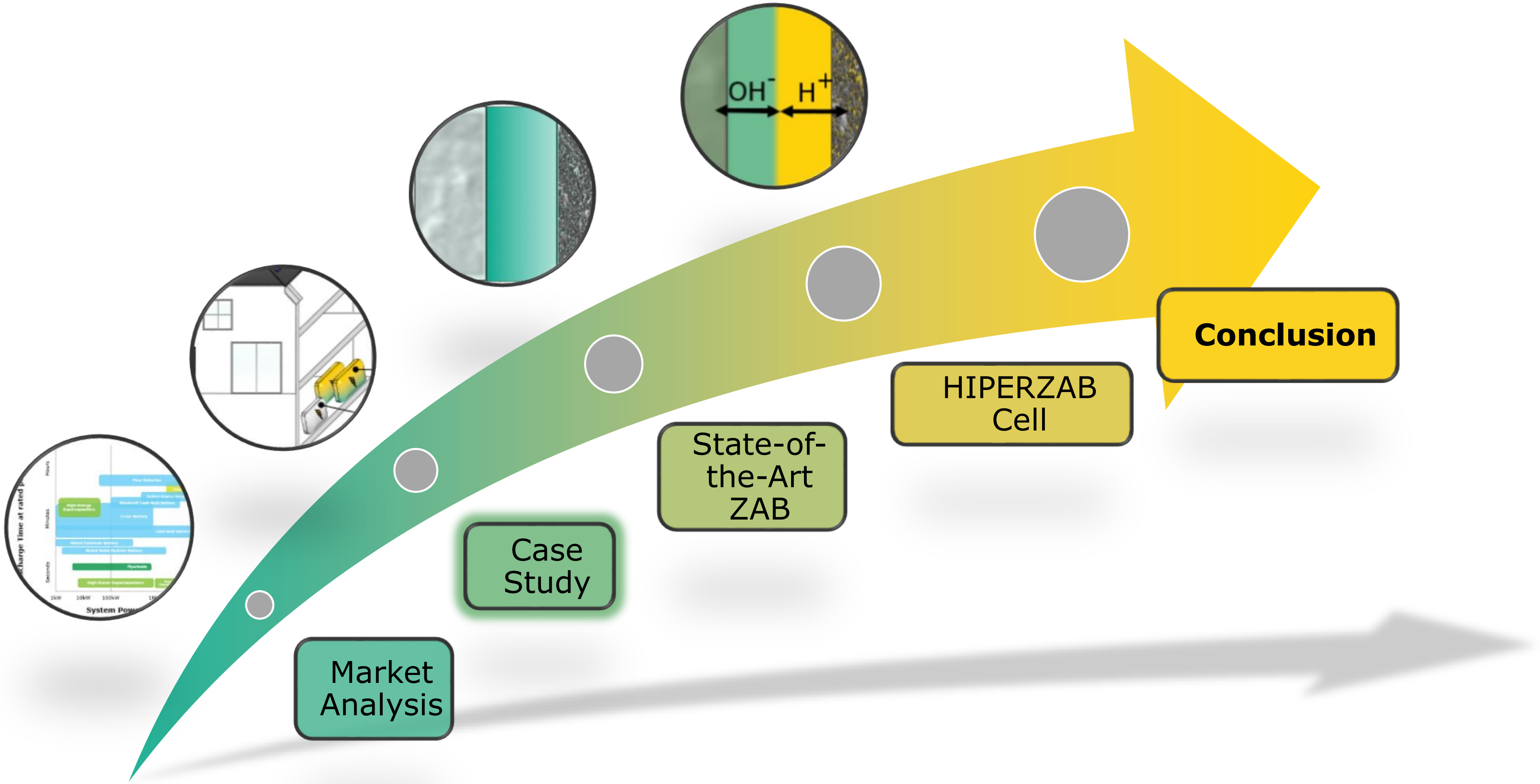

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Conclusion

Project is in its productive phase:
- Problems identified, solved or worked on

Integration of components started

Next big step: first prototype (Planed: June 2026)

Will we reach the breakthrough for secondary Zinc-Air-Batteries?

Thank you

Julian Seiler